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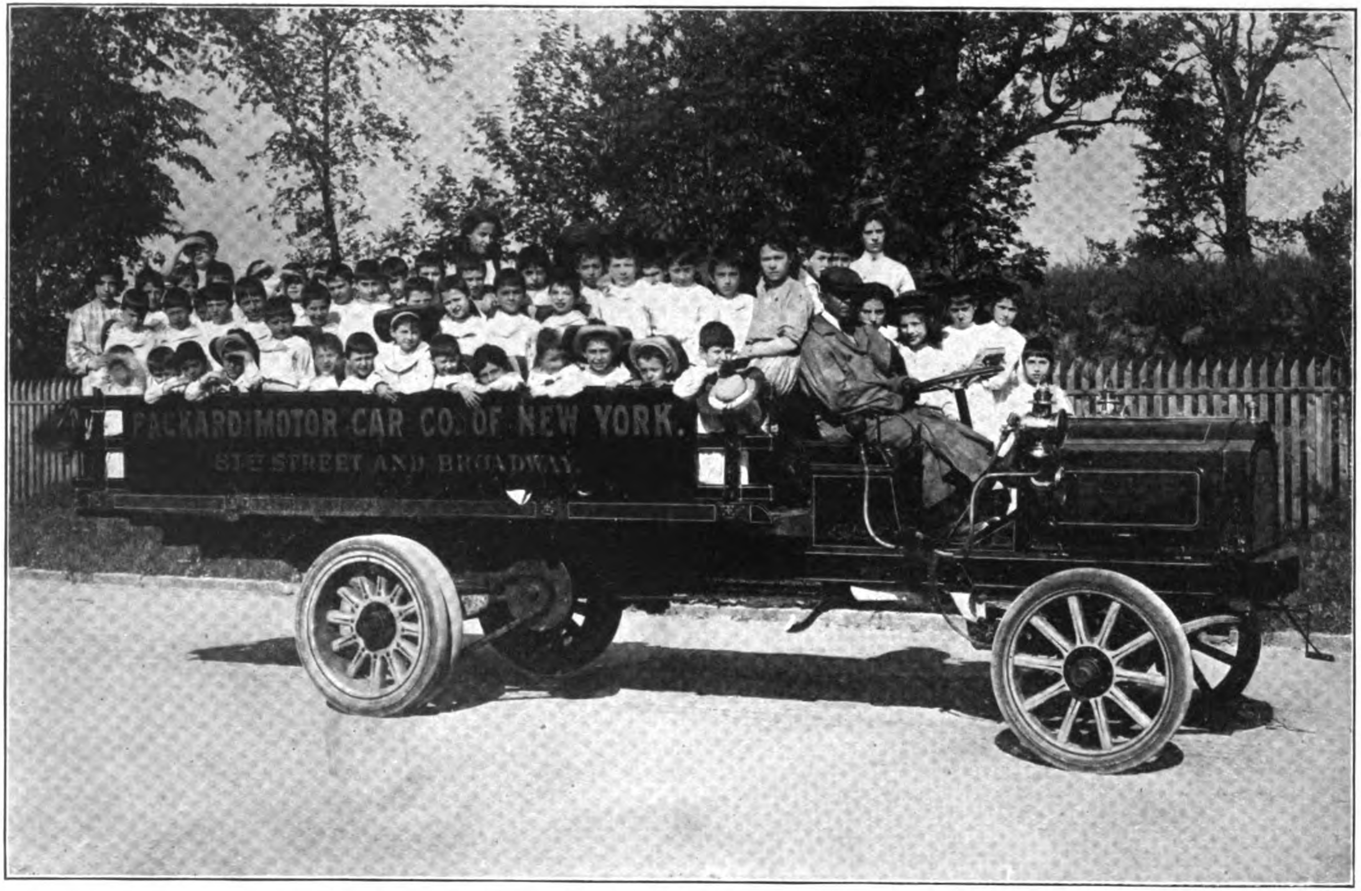
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A General Reference Work on

THE CONSTRUCTION, OPERATION, AND CARE OF GASOLINE, STEAM, AND
ELECTRIC AUTOMOBILES, INSTRUCTION IN DRIVING, COMMERCIAL
VEHICLES, MOTORCYCLES, MOTOR BOATS, AERIAL VEHICLES,
SELF-PROPELLED RAILWAY CARS, ETC.

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE
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FOUR VOLUMES

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Motorcycles, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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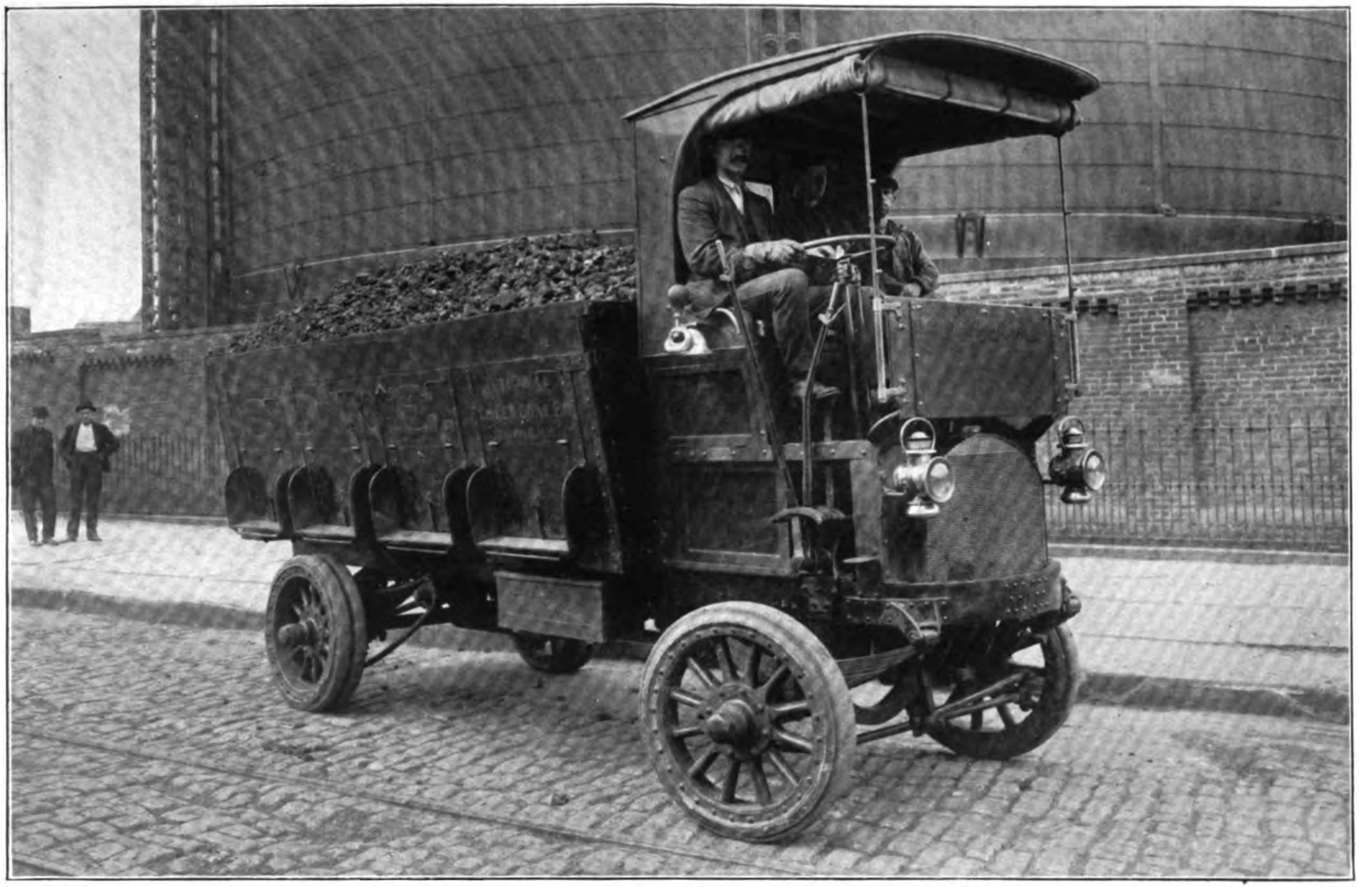

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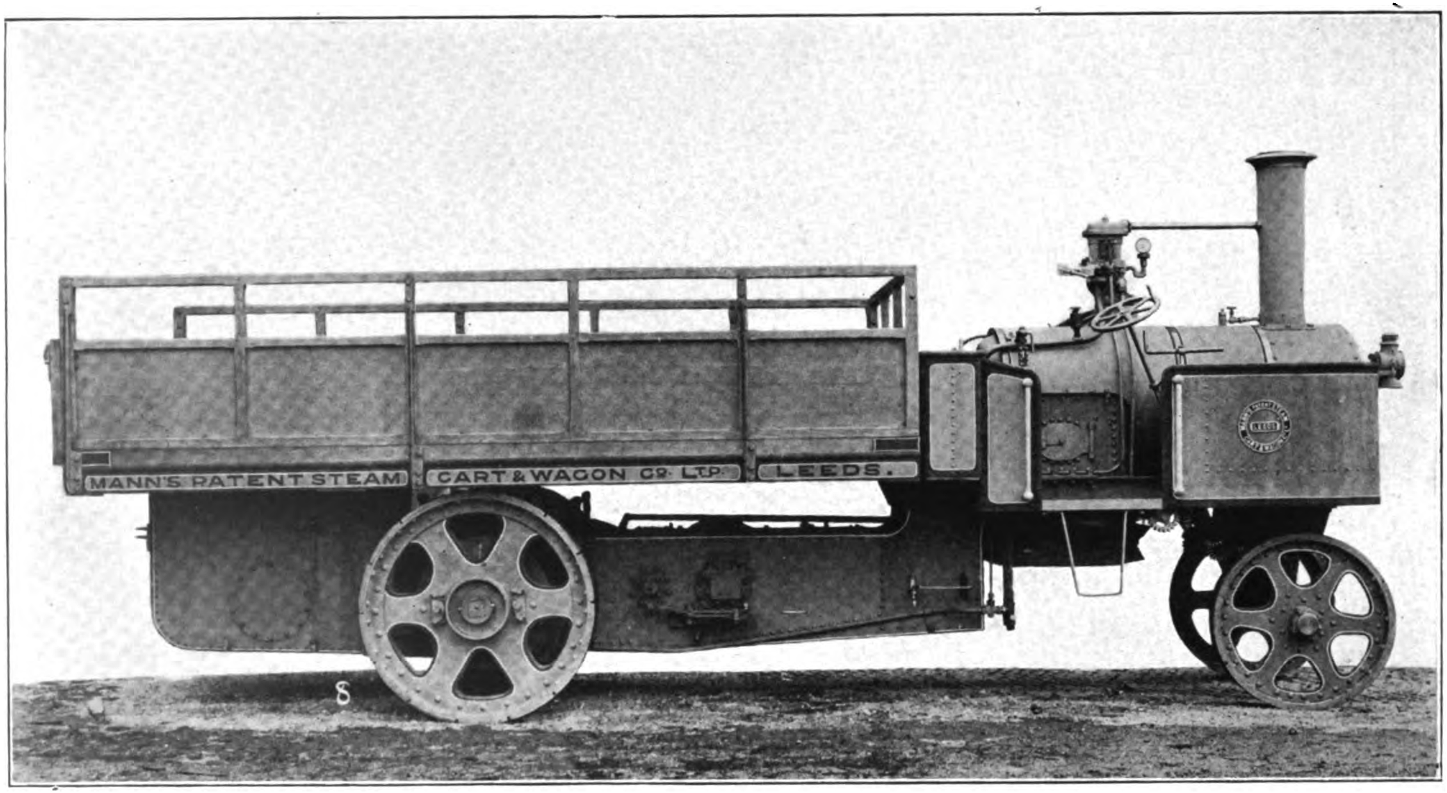

A SEVEN-TON STEAM WAGON OF ENGLISH MANUFACTURE

Foreword

WITHIN recent years the internal-combustion motor and the self-propelled vehicle have become such important factors in the evolution of industrial, commercial, and social life, that a distinct need has been created for an authoritative work of reference embodying the results and methods of the latest approved practice in the construction, care, and operation of the various types of motor cars and other vehicles driven by gas, steam, and electricity, and in allied branches of this rapidly developing field of apparently unlimited possibilities. It is the purpose of the Cyclopedia of Automobile Engineering to fill this acknowledged need.

¶ The application of the internal-combustion motor, the steam generator, the storage battery and electric motor, to the development of types of mechanically propelled road carriages and motor boats, is a far-reaching engineering problem of great difficulty. The same is true of the airship motor and the application of the gas engine to the development of efficient and economical methods of power production for aërial navigation. While not all details of these problems have as yet been finally worked out or reduced to standard practice, sufficient progress has been made to assure results of permanent value. In so far as these results are embodied in the constructions used in typical modern cars, they are presented in these pages without any attempt at great refinement of engineering subtleties, but with all explanation of details essential to a working knowledge.

¶ Special stress is laid on the practical as distinguished from the merely theoretical or descriptive form of treatment, so that these volumes will be found especially adapted for purposes of self-instruction. They are designed not only to meet the requirements of instruction for the novice, but also to serve as a reference work replete with information and suggestions of the utmost practical value to the most experienced chauffeur and engineer.

¶ The method adopted in the preparation of the Cyclopedia of Automobile Engineering is that which the American School of Correspondence has developed and employed so successfully for many years. It is not an experiment, but has stood the severest of all tests — that of practical use — which has demonstrated it to be the best method yet devised for the education of the busy man.

¶ For purposes of ready reference and timely information so frequently needed in automobile operation and construction, it is believed that these volumes will be found to meet every requirement.

¶ Grateful acknowledgment is due the corps of authors and collaborators — engineers of wide practical experience, and teachers of well-recognized ability — without whose co-operation this work would have been impossible.

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PRESIDENT TAFT IN THE OFFICIAL WHITE STEAMER
Courtesy of the Lovell-McConnell Mfg. Co., Newark, N. J.

STEAM AUTOMOBILES

PART I

CHARACTERISTIC FEATURES OF STEAM CARS

Steam automobiles are propelled by engines similar in principle to stationary and marine engines, and in form somewhat resembling the latter. They are, however, of small size, and operate under much higher pressure—usually from 300 to 500 pounds, but sometimes even higher.

The fuel is gasoline or kerosene, according to the type of burner, and is vaporized by heat, mixed with air, and burned in a burner similar in principle to those of gasoline cooking stoves, but of a much larger size.

Steam is generated either in a boiler similar in principle to most portable steam boilers, or in a special device known as a *flash steam generator,* which is described on Page 59. The engine is controlled by a throttle valve and a "cut-off" mechanism, which latter is explained under "Steam Engine Principles," Page 15. The burner is regulated by automatic devices to supply more or less fire according to the demand for steam. The water feed to the boiler is regulated either by hand or automatically, depending on the system used.

Most automobile steam engines have two cylinders. In some engines steam from the boiler goes direct into each cylinder, does work by expansion against the piston, and is discharged into the atmosphere at the end of the stroke. These are known as *simple engines.* In other engines the steam enters one cylinder, expands only partially, and is then transferred to a larger cylinder in which the expansion is completed before the steam is discharged. These are known as *compound engines.*

For reasons explained later, steam cars do not ordinarily require a change in gear ratio to enable them to negotiate difficult roads and hills. This renders their operation extremely simple, and to the amateur is the most attractive feature of the steam car. Some cars, notably the White, are provided with a low gear for emergency use

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only. With this gear the engine may run twice as fast as with the regular gear, for equal car speed, thus giving it double the *purchase* to overcome road resistance.

Owing to the fact that in steam cars the fuel is supplied to the burner under a pressure of from 50 to 100 pounds, and that the steam pressure is also high, a certain amount of watching is required to keep the various joints, gaskets, and other connections tight. A gasoline leak would be especially apt to lead to disaster, as the gasoline might be squirted some distance by the pressure and its vapor could readily catch fire from the flame under the boiler. Such things are prevented by regular inspection of the gasoline piping and connections, and vigilance in this regard must be accepted as the price of safe and satisfactory service.

MECHANICAL ELEMENTS OF THE STEAM ENGINE

The diagram, Fig. 1, shows in outline the elementary working parts of a simple double-acting steam engine. *A* is the cylinder, and steam enters under pressure from the boiler at *B*. *C* and *D* are respectively the outer and inner cylinder heads, and *E* is the piston, which is a steam-tight sliding fit in the cylinder. *F* is the piston rod, which passes through a stuffing box *G* and is secured to the crosshead *H* sliding between two stationary guides *I J*. *K* is the connecting rod, which is jointed to the crosshead by the wrist pin *L* and whose other end bears against the crank pin *M* at the end of the crank *N*. *O* is the crank shaft (seen endwise) which turns in stationary bearings in the engine frame. The piston moves back and forth in the cylinder under the pressure of steam introduced first into one and then into the other end of the cylinder, and its reciprocating motion is converted by the connecting rod and crank into rotating motion at the shaft.

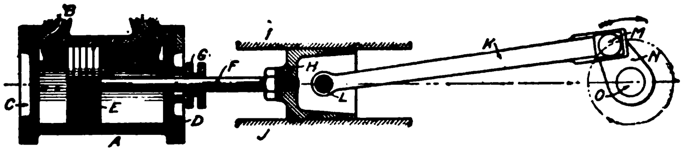


Fig. 1. Elements of Simple Steam Engine.

In Fig. 2 and Fig. 3 is shown a stationary horizontal steam engine working on the general lines of Fig. 1. Aside from the elements already mentioned and listed in the table, the things of chief importance are the flywheels *P* and the valve mechanism. The valve is operated by an eccentric *I* through an eccentric strap *Y* and rod *J* connecting at *K* to the valve stem *L*. The valve itself, *X*, is of the ordinary slide type, called from its shape the "*D*" *slide valve*. It admits steam from steam chest *M* through steam ports *W* to first one and then the other end of the cylinder, and affords an outlet for the exhaust steam to the central or exhaust port between the steam ports. The valve moves with a steam-tight fit over the faces of the ports.

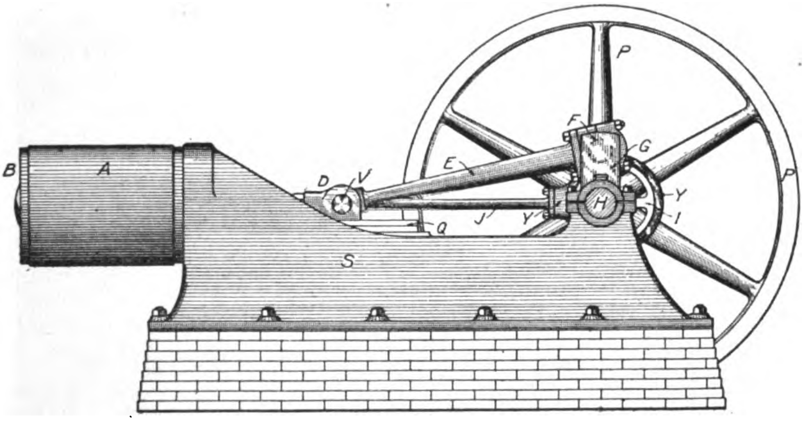


Fig. 2. Stationary Engine—Side View.

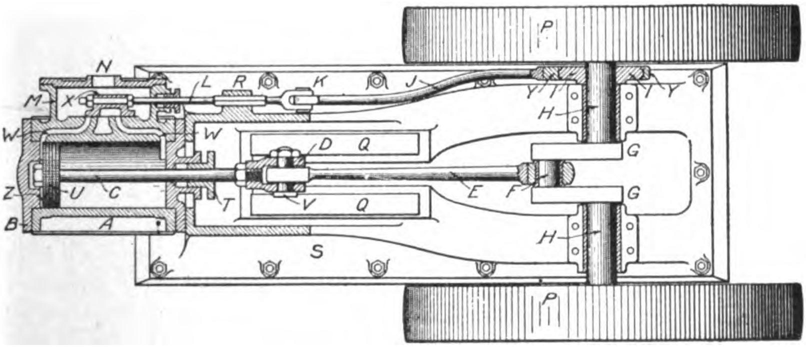


Fig. 3. Stationary Engine. Plan View.

A, Cylinder. *B*, Outer cylinder head. *C*, Piston rod. *D*, Crosshead. *E*, Connecting rod. *F*, Crank pin. *G*, Crank. *H*, Crank shaft. *I*, Eccentric. *J*, Eccentric rod. *K*, Eccentric crosshead. *L*, Valve stem. *M*, Steam chest. *N*, Steam pipe connection. *PP*, Flywheels. *Q*. Crosshead guides. *R*, Valve stem guide. *S*, Engine frame. *T*. Stuffing box. *U*, Piston. *V*, Wrist pin. *WW*, Steam ports. *X*, Slide valve. *Y*, Eccentric strap. *Z*, Clearance space between piston and cylinder head at end of stroke.

HEAT AND WORK

HEAT TRANSMISSION

All forms of energy, such as light, sound, electricity, and heat, are believed to be different forms of vibration, either of the molecules of material substances or of the ether which is believed to pervade all space.

Energy is indestructible, but any form of energy may be converted into any other form. *E. g.*, electricity may be converted into light, heat, or mechanical work, or it may produce sound by setting the air in vibration.

Heat may be transmitted from one body to another in three ways: viz, *radiation and absorption*, *conduction*, and *convection*.

Radiation and Absorption. Radiation is the transfer of heat from one body to another body not in contact with it. It takes place equally well in air or *in vacuo*. The rate of heat transferred depends partly on the distance separating the two bodies, and partly on the nature of their surfaces. In general, light colored and polished metal surfaces radiate heat more slowly than rough and dark colored surfaces. The laws governing absorption are the same as those governing radiation. A body with a good radiating surface will readily absorb heat radiated to it from a more highly heated body. If the colder body has a polished surface, it will reflect back a portion of the heat it receives, and the hot body will, therefore, cool more slowly.

Conduction. Conduction is the transfer of heat through the substance of a body—solid or liquid—to other portions of the same body, or to another body in physical contact therewith. Metals are the best conductors of heat, but some metals, such as copper, are better conductors than others. Other solids, such as stone, wood, etc., rank after the metals. Liquids are very poor, and gases still poorer, conductors of heat. A vacuum is perfectly non-conducting, though radiation may still take place through it.

Convection. Convection is the term applied to the absorption of heat by moving liquids or gases in contact with heated surfaces. If a blast of air be directed on a piece of hot iron, it cools far more rapidly than it would in still air. The reason is that, as the air is a poor conductor, its molecules do not transmit heat readily from one to the next, but if each molecule on becoming heated is immediately replaced, heat is rapidly transferred. This property of air of taking up heat rapidly when blown over a hot surface is employed in gasoline automobiles to cool the so-called *radiators.* In reality, the heat radiated cuts a small figure compared with that dispersed by convection.

What has just been said regarding air is equally true of other gases. It is also true of most liquids. If a tea-kettle full of water were heated from the top instead of from beneath, the bottom would be a long time getting hot. The rapidity with which it actually heats is due to the fact that the water heated by contact with the bottom of the kettle expands slightly, thereby being reduced in density. A circulation is therefore set up, the heated water rising and the cold water descending to take its place.

TABLE I

Relative Heat-Conducting Power of Metals

Metals	*C. & J.	†W. & F.
Silver	1000	1000
Gold	981	532
Copper, rolled	845	736
Aluminum	665	...
Zinc, rolled	641	...
Wrought iron	436	119
Steel	397	116
Cast iron	359	...
Lead	287	85

*Calvert & Johnson. † Weidmann & Franz.

TABLE II

Relative Radiating and Reflecting Power of Different Substances

	Radiating or Absorbing Power	Reflecting Power
Lampblack	100	0
Ivory, jet, marble	93 to 98	7 to 2
Ordinary glass	90	10
Cast iron, bright polished	25	75
Mercury, about	23	77
Steel, polished	17	83
Tin	15	85
Brass, bright polished	7	93
Copper, hammered	7	93
Silver, polished	3	97

Almost all substances expand with rise of temperature. Solids expand least, and in some the expansion is imperceptible. Liquids expand about as much as solids, sometimes slightly more. Gases and vapors expand a great deal if free to do so.

Before considering the expansion of gases under changes in temperature, let us see how they act when the temperature is unchanged. A gas is perfectly elastic, *i. e.*, if not confined in any way it would expand indefinitely. The attraction of gravity is all that prevents the atmosphere surrounding the globe from dispersing into infinite space. When air is partly exhausted from a closed vessel, the remainder, no matter how small, expands so as to distribute itself equally throughout the vessel.

If a cubic foot of air at atmospheric pressure be compressed into one-half cubic foot without change in temperature, its pressure will be precisely twice what it was before. In speaking of gas pressures in this manner, it is customary to deal with *absolute pressures*, *i. e.*, pressures above a perfect vacuum. Thus atmospheric pressure at sea level is approximately 14.7 pounds per square inch, and a cubic foot of air reduced one-half in volume will have an absolute pressure of 29.4 pounds. If again compressed into half the space, its pressure will again be doubled, and so on.

This relation of pressure and volume is expressed in *Boyle's Law*, which states that, *so long as the temperature is unchanged, the product of the pressure and volume of a given weight of gas is constant.* That is

$$P V = C$$

This is the most important of all the laws of gases.

Fig. 4 expresses the relation between volume and pressure of a given weight of air starting at atmospheric pressure and compressed to a pressure of 500 pounds without change in temperature, also expanded to a pressure of one pound absolute. Horizontal distances represent volumes, the volume at atmospheric pressure being unity; and vertical distances represent absolute pressures. To find the pressure of the air for any volume greater or less than one, locate the given volume on the base line, then, from this point, read up to the curve and find the desired pressure by moving horizontally from the curve to the scale at the left.

As heat is a mode of motion, it follows that when *all* heat is withdrawn motion ceases, and the molecules, even of a gas, become fixed. From experiments and theoretical considerations the *absolute zero*, representing the absence of all heat, is believed to be − 273° C., or approximately − 460° F. In most theoretical studies of the behavior of gases, temperatures are reckoned from absolute zero instead of from the arbitrary zeroes of the conventional thermometer.

When a gas of given weight at an absolute temperature of 273 degrees—*i. e.*, 0° on the customary scale—is raised in temperature one degree without change in pressure, its volume is increased $\frac{1}{273}$. A second degree of added temperature increases its volume the same amount, and so on. In other words, for each degree Centigrade of added temperature its volume is increased $\frac{1}{273}$ of its volume at 273° A.

If degrees Fahrenheit are taken instead of Centigrade, the expansion is $\frac{1}{492}$ of the volume at 32° F. for each degree of rise in temperature. Five degrees C. equal nine degrees F.

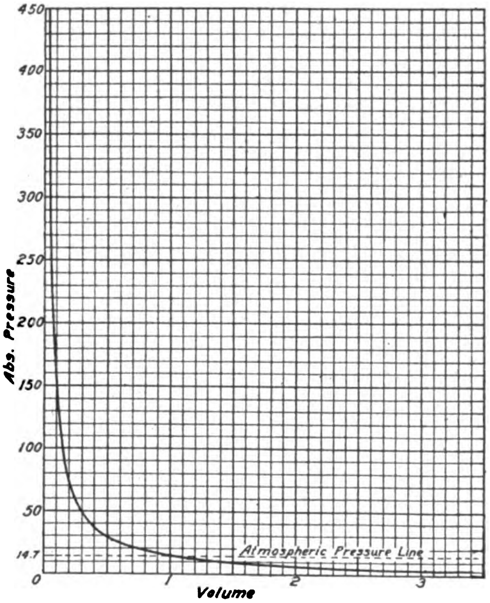


Fig. 4. Relation Between Volume and Pressure of Air.

If the gas thus heated is so confined that it cannot expand, it will suffer an increase in pressure in the same proportion, *i. e.*, $\frac{1}{273}$ of its pressure at 0° C. for each degree Centigrade. If the gas, instead of being heated, is cooled, its shrinkage in the one case or its loss of pressure in the other will follow the same rule as above. Theoretically it would follow that at − 273° C.—absolute zero—the gas would have no volume at all. Of course that would be impossible, but at ordinary temperatures the gases behave as if the assumption were true.

HEAT TRANSFORMATION

Specific Heat. The temperature of a body and the heat it contains are two different things. A gallon of water at 100° F. contains twice as much heat as half a gallon at the same temperature. That is to say, twice as much heat was imparted to it in raising it to that temperature.

Like quantities of different substances at the same temperature do not always contain the same quantity of heat. A pound of water contains more heat than a pound of oil or alcohol at the same temperature. It requires 7.7 times as much heat to raise a pound of water one degree in temperature as a pound of cast iron.

The quantity of heat required to change the temperature of a given weight of a substance one degree, compared with that required to change the temperature of the same weight of water a like amount, is called the *specific heat* of that substance.

TABLE III

Specific Heats of Various Substances

SOLIDS			
Copper	0.0951	Tin	0.0562
Gold	0.0324	Steel (soft)	0.1165
Wrought iron	0.1138	Zinc	0.0956
Glass	0.1937	Brass	0.0939
Cast iron	0.1298	Ice	0.5040
Lead	0.0314	Charcoal	0.2410
Silver	0.0570		
LIQUIDS			
Water	1.0000	Benzine	0.4500
Mercury	0.0333	Ether	0.5034
Alcohol (absolute)	0.7000		

The quantity of heat required to raise the temperature of one pound of water one degree F. is known as the *British Thermal Unit* (B. T. U.). Another unit is the *calorie,* which is the quantity of heat required to raise the temperature of one kilogram (2.2046 lbs.) of water one degree Centigrade. One calorie equals 3.968 B. T. U.

Force. Force is defined as that which produces, or tends to produce, motion, and in practical work is usually expressed in units of weight, *e. g.*, pounds, kilograms, or tons. A force may exist without any resulting motion and, therefore, without work being done. For example, the weight of any object represents the force of gravity attraction between the earth and that body. The atmosphere exerts a pressure or force of approximately 14.7 pounds per square inch at sea level.

Work. Work is done when force is exerted by or on a moving body, and is measured by the product of the force into the distance through which it is exerted. A convenient unit of work is the *foot pound*, which is the work done in lifting a weight of one pound against the force of gravitation a vertical distance of one foot, or exerting a force of one pound in any direction through a distance of one foot.

Power. Power expresses the rate at which work is done. If a foot pound of work is performed in a minute, the power is small. If it is done in a second, the power is 60 times as great. The customary unit of power is the horse-power, which is 33,000 foot pounds per minute. Whether a force of 33,000 pounds be exerted through one foot of distance, or one pound be exerted through 33,000 feet in the same time, the power is the same.

Mechanical Equivalent of Heat. Heat may be converted into work or work into heat. Experiments have been made in which water was agitated in a closed vessel by means of paddles run by falling weights and the resulting rise in temperature of the water carefully determined. From these and other experiments it has been ascertained that one British Thermal Unit is the equivalent of 778 foot pounds of work. That is, a weight of one pound falling 778 feet, or 778 pounds falling one foot, developed sufficient energy to raise one pound of water one degree F. in temperature. A horse-power, therefore, equals 42.416 B. T. U. per minute. The combustion of one pound of either gasoline or kerosene liberates approximately 19,900 B. T. U., but the kerosene is heavier for equal bulk. One U. S. gallon of gasoline weighs about 5.6 lbs.; of kerosene, about 6.25 lbs. The combustion of a gallon of kerosene per hour develops theoretically about 49 horse-power. Owing to heat losses in the boiler and exhaust, and to radiation, etc., only a small fraction of this energy can be converted into useful work.

THERMODYNAMICS OF STEAM

Latent Heat. If water be heated in an open vessel it will reach a temperature of approximately 212° F. (100 °C.) and will then boil away without further rise in temperature. The added heat is absorbed in converting the water into steam.

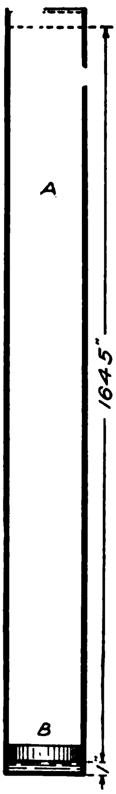


Fig. 5. Expansion of Water into Steam.

It takes far more heat to convert water into steam than to raise its temperature. A pound of water heated to boiling from 32° F. absorbs only 180 B. T. U., but in boiling away at 212° F. it absorbs 966 B. T. U. additional. At atmospheric pressure the volume of the steam is 1,646 times the volume of the water whence it came. This bulk of steam must displace an equal bulk of air, and part of the heat energy represented by the steam has been spent in pushing back the air to give it room. This will be clearer from the sketch, Fig. 5, showing a long tube open at the top and containing a little water at the bottom. On top of the water is a piston supposed to be air tight and without weight or friction. If the water be boiled into steam, the piston will be pushed upward against the atmospheric pressure a distance equal to *1645 × the original depth of the water.* The work in foot-pounds thus done will be *14.7 × the area of the piston in square inches × the distance in feet through which it has moved.* Approximately 7.45 per cent of the heat imparted to the steam represents work done against the atmosphere; the remainder is spent in overcoming the mutual attraction of the molecules of water. The heat which has been absorbed by the change in state from water to steam without change in temperature is called the *latent heat of vaporization.*

If a vessel containing water at 212° F., which is the *atmospheric boiling point,* be put under the receiver of an air pump and the air partially exhausted, boiling will take place spontaneously without further addition of heat. At the same time the temperature of the water will decrease, because part of the heat contained in it has been absorbed by the conversion of water into vapor. If the air pump keeps on working, the water will boil continuously, while its temperature steadily descends. If the experiment be carried far enough, with the vessel so supported that it can absorb little or no heat from adjacent objects, and if the vapor given off be rapidly absorbed, *e. g.*, by placing a tray of quick-lime or sulphuric acid adjacent, the water may actually be frozen by its own evaporation.

This experiment shows that the boiling point of water—and this includes other liquids also—is not a fixed temperature, but depends on the pressure. All volatile liquids when exposed to partial or complete vacuum give off vapor; on the contrary, this vapor when subjected to pressure partially re-condenses and a higher temperature is needed to produce boiling. Under an absolute pressure of 147 pounds or 10 "atmospheres" the boiling point is 356.6° F. At 500 pounds absolute pressure the boiling point is 467.4° F. (242° C.).

The "total" heat of steam at the boiling point corresponding to a given pressure is the sum of its latent heat of vaporization and the heat contained at the same temperature in the water whence the steam was formed. The total heat of steam increases slowly, but the latent heat diminishes nearly in proportion as the boiling point rises. The space occupied by a given weight of steam diminishes approximately in proportion to the increase in pressure. In this respect the steam resembles a perfect gas without change of temperature in accordance with Boyle's Law.

Table IV shows the relation between pressure, temperature, latent heat, total heat, and weight of saturated steam,

The experiment just cited of producing spontaneous boiling in water by exhausting the air above it, may be duplicated with hot water at any temperature and pressure. For example, the boiling point of water under 100 pounds absolute pressure is 327.6° F. If in a boiler containing water at that temperature and pressure, the pressure be reduced to 50 pounds by withdrawal of steam, the water will boil spontaneously, absorbing its own heat in doing so, till it reaches a temperature of 280.9° F. which is the boiling point for 50 pounds absolute pressure.

Cause of Boiler Explosions. Owing to the property of giving off steam under reduction of pressure, every steam boiler constitutes a reservoir of energy, which may be drawn upon to carry the engine through a temporary period of overload. In other words, the boiler will give out steam faster than the fire generates steam, the difference

TABLE IV

Properties of Saturated Steam

Pressure in pounds per sq. in. above vacuum.	Temperature in degrees Fahrenheit.	Heat in liquid from 32° in units.	Heat of vaporization, or latent heat in heat units.	Total heat in heat units from water at 32°.	Density or weight of 1 cubic foot in pounds.	Volume of 1 pound in cubic feet.	Total pressure above vacuum.
1	101.99	70.0	1043.0	1113.1	0.00299	334.5	1
2	126.27	94.4	1026.1	1120.5	0.00576	173.6	2
3	141.62	109.8	1015.3	1125.1	0.00844	118.5	3
4	153.09	121.4	1007.2	1128.6	0.01107	90.1	4
5	162.34	130.7	1000.8	1131.5	0.01366	73.21	5
6	170.14	138.6	995.2	1138.8	0.01622	61.67	6
7	176.90	145.4	990.5	1135.9	0.01874	53.37	7
8	182.92	151.5	986.2	1137.7	0.02125	47.06	8
9	188.33	156.9	982.5	1139.4	0.02374	42.12	9
10	193.25	161.9	979.0	1140.9	0.02621	38.15	10
14.7	212.00	180.9	965.7	1146.6	0.03794	26.36	14.7
15	213.03	181.8	965.1	1146.9	0.03826	26.14	15
20	227.95	196.9	954.6	1151.5	0.05023	19.91	20
25	240.04	209.1	946.0	1155.1	0.06199	16.13	25
30	250.27	219.4	938.9	1158.3	0.07360	13.59	30
35	259.19	228.4	932.6	1161.0	0.08508	11.75	35
40	267.13	236.4	927.0	1163.4	0.09644	10.37	40
45	274.29	243.6	922.0	1165.6	0.1077	9.287	45
50	280.85	250.2	917.4	1167.6	0.1188	8.414	50
55	286.89	256.3	913.1	1169.4	0.1299	7.696	55
60	292.51	261.9	909.3	1171.2	0.1409	7.097	60
65	297.77	267.2	905.5	1172.7	0.1519	6.583	65
70	302.71	272.2	902.1	1174.3	0.1628	6.143	70
75	307.38	276.9	898.8	1175.7	0.1736	5.762	75
80	311.80	281.4	895.6	1177.0	0.1843	5.426	80
85	316.02	285.8	892.5	1178.3	0.1951	5.126	85
90	320.04	290.0	889.6	1179.6	0.2058	4.859	90
95	323.89	294.0	886.7	1180.7	0.2165	4.619	95
100	327.58	297.9	884.0	1181.9	0.2271	4.403	100
105	331.13	301.6	881.3	1182.9	0.2378	4.205	105
110	334.56	305.2	878.8	1184.0	0.2484	4.026	110
115	337.86	308.7	876.3	1185.0	0.2589	3.862	115
120	341.05	312.0	874.0	1186.9	0.2695	3.711	120
125	344.13	315.2	871.7	1186.9	0.2800	3.571	125
130	347.12	318.4	869.4	1187.8	0.2904	3.444	130
140	352.85	324.4	865.1	1189.5	0.3113	3.212	140
150	358.26	330.0	861.2	1191.2	0.3321	3.011	150
160	363.40	335.4	857.4	1192.8	0.3530	2.833	160
170	368.29	340.5	853.8	1194.3	0.3737	2.676	170
180	372.97	345.4	850.3	1195.7	0.3945	2.535	180
190	377.44	350.1	847.0	1197.1	0.4153	2.408	190
200	381.73	354.6	843.8	1198.4	0.4359	2.294	200
225	391.79	365.1	836.3	1201.4	0.4876	2.051	225
250	400.99	374.7	829.5	1204.2	0.5393	1.854	250
275	409.50	383.6	823.2	1206.8	0.5913	1.691	275
300	417.42	391.9	817.4	1209.3	0.644	1.553	300
325	424.82	399.6	811.9	1211.5	0.696	1.437	325
350	431.90	406.9	806.8	1213.7	0.748	1.337	350
375	438.40	414.2	801.5	1215.7	0.800	1.250	375
400	445.15	421.4	796.3	1217.7	0.853	1.172	400
500	466.57	444.3	779.9	1224.2	1.065	.939	500

TABLE IV—Continued

Properties of Saturated Steam

Temperature in degrees Fahrenheit.	Total pressure above vacuum.	Heat in liquid from 32° in units.	Heat of vaporization, or latent heat in heat units.	Total heat in heat units from water at 32°.	Density or weight of 1 cubic foot in pounds.	Volume of one pound in cubic feet.	Temperature in degrees Fahrenheit.
32	0.089	0.	1091.7	1091.7	0.0003	3387.	32
60	0.254	28.12	1072.1	1100.2	0.0008	1234.	60
90	0.692	58.04	1051.4	1109.4	0.0021	474.6	90
120	1.683	88.10	1034.4	1118.5	0.0049	204.4	120
140	2.877	108.2	1016.4	1124.6	0.0081	123.2	140
150	3.706	118.3	1009.4	1127.7	0.0103	97.03	150
160	4.728	128.4	1002.3	1130.7	0.0130	77.14	160
170	5.98	138.5	995.3	1133.8	0.0162	61.85	170
180	5.70	148.5	988.3	1136.8	0.0200	50.01	180
190	9.33	158.6	981.3	1139.9	0.0245	40.73	190
200	11.52	168.7	974.2	1142.9	0.0299	33.40	200
210	14.12	178.8	967.2	1146.0	0.0363	27.57	210
220	17.19	188.9	960.1	1149.0	0.0435	22.98	220
225	18.91	193.9	956.7	1150.6	0.0476	20.99	225
230	20.78	198.9	953.2	1152.1	0.0521	19.20	230
235	22.80	204.0	949.6	1153.6	0.0569	17.59	235
240	24.98	209.0	946.1	1155.1	0.0619	16.14	240
245	27.33	214.1	942.6	1156.7	0.0674	14.83	245
250	29.86	219.1	939.1	1158.2	0.0733	13.65	250
255	32.57	224.1	935.6	1159.7	0.0795	12.57	255
260	35.48	229.2	932.0	1161.2	0.0862	11.60	260
265	38.60	234.2	928.6	1162.8	0.0933	10.72	265
270	41.94	239.3	925.0	1164.3	0.1008	9.918	270
275	45.51	244.3	921.5	1165.8	0.1088	9.187	275
280	49.33	249.3	918.0	1167.3	0.1173	8.521	280
285	53.39	254.4	914.5	1168.9	0.1264	7.913	285
290	57.72	259.4	911.0	1170.4	0.1359	7.356	290
295	62.33	264.4	907.4	1171.9	0.1461	6.847	295
300	67.22	269.5	903.9	1173.4	0.1567	6.380	300
305	72.42	274.5	900.5	1175.0	0.1680	5.952	305
310	77.83	279.6	896.9	1176.5	0.1799	5.558	310
315	83.77	284.8	893.2	1178.0	0.1925	5.195	315
320	89.95	290.0	889.5	1179.5	0.2058	4.861	320
325	96.48	295.2	885.9	1181.1	0.2197	4.552	325
330	103.38	300.5	882.1	1128.6	0.2343	4.267	330
335	110.66	305.7	878.4	1184.1	0.2498	4.004	335
340	118.34	310.9	874.7	1185.6	0.2660	3.760	340
345	126.43	316.1	871.1	1187.2	0.2830	3.534	345
350	134.95	321.4	867.3	1188.7	0.3008	3.324	350
355	143.91	326.6	863.6	1190.2	0.3195	3.130	355
360	153.33	331.8	859.9	1191.7	0.3391	2.949	360
365	163.22	337.1	856.2	1193.3	0.3597	2.780	365
370	173.60	342.3	852.5	1194.8	0.3812	2 623	370
375	184.49	347.5	848.8	1196.3	0.4038	2.476	375
380	195.91	352.8	845.0	1197.8	0.4276	2.338	380
385	207.87	358.0	841.4	1199.4	0.4521	2.212	385
390	220.39	363.2	837.7	1200.9	0.4780	2.092	390
395	233.50	368.4	834.0	1202.4	0.5051	1.980	395
400	247.21	373.7	830.2	1203.9	0.5336	1.874	400
405	261.55	378.9	826.6	1205.5	0.5633	1.775	405
410	276.54	384-1	822.9	1207.0	0.5945	1.682	410
415	292.21	389.4	819.1	1208.5	0.6270	1.595	415
420	308.57	394.6	815.4	1210.0	0.6610	1.512	420
425	325.65	399.8	811.8	1211.6	0.6670	1.434	425

being supplied from the heat stored in the water itself. This is an exceedingly useful feature of the ordinary steam boiler. At the same time, and for the same reason, it is a source of danger in case of rupture of the boiler shell. If a boiler explosion involved simply the release of the steam already formed it would not be so serious a matter; but when a seam starts to "go" the adjacent portions are unable to carry the abnormal strain put upon them, and the result is a rent of such proportions as to release almost instantly the entire contents of the boiler. The hot water thus suddenly liberated at high temperature bursts into steam till the whole mass drops to a temperature of 212 degrees, and this steam is many hundred times the volume of the water whence it came. It is to this fact that the violence of boiler explosions is due.

To take an extreme case, if a boiler bursts under 500 pounds pressure, approximately thirty-seven per cent of the contained water will pass instantly into steam, and at atmospheric pressure the volume of the steam will be over 600 times the volume of the entire original liquid contents of the boiler.

Automobile boilers and steam generators are so designed as to minimize the danger of explosion, and only ordinary care is needed to insure entire safety.

Superheating. The foregoing paragraphs have dealt exclusively with steam at the boiling temperature due to its pressure. Such steam is called *saturated steam.* Steam will not suffer a reduction of temperature below this point; if heat be absorbed from it a portion will condense. On the other hand, steam isolated from the water whence it came may be raised in temperature indefinitely. It is then called *superheated steam.* The more it is superheated the more nearly does it act like a perfect gas.

Superheated steam is preferred for power purposes to saturated steam, for the reason that the latter condenses more or less, both in the pipes on its way to the engine, and in the engine itself. Steam that condenses thus is a total loss, and it is more economical to add sufficient heat to it—before it reaches the engine—to supply radiation losses, etc., without cooling the steam to the saturation point. To accomplish this in automobiles, the steam from the boiler is led through one or more pipes exposed to the maximum temperature of the fire. These pipes are called *superheaters,* or *superheating pipes.*

STEAM ENGINE PRINCIPLES

The leading mechanical elements of the steam engine have been briefly described. It remains now to show the precise manner in which the steam is used.

The Slide Valve. Fig. 6 represents an elementary slide valve. In order to indicate the movements of the crank pin and the valve eccentric on one drawing, the crank shaft center is located at *A*. *B* represents the crank pin center with the piston *C* at the inner end of its stroke. The larger dotted circle is the crank pin circle, and the small circle is that in which the center *D* of the eccentric moves. With the crank pin traveling as the arrow shows, the valve is in mid-position when the piston starts to move, and the first effect of its movement is to uncover the steam port *E*, at the same time establishing communication between port *E′* and exhaust port *F*, Fig. 7. At half piston stroke the ports are wide open and the valve starts to return, Fig. 8. When the crank pin reaches the outer dead center *G* the ports are again closed.

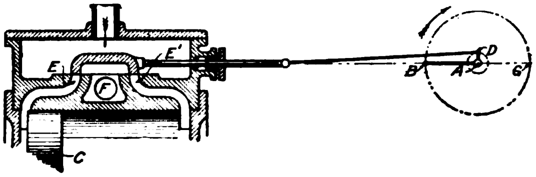


Fig. 6. Elementary Slide Valve.

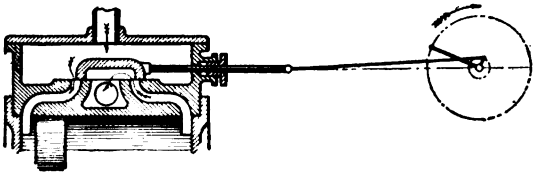


Fig. 7. Elementary Slide Valve.

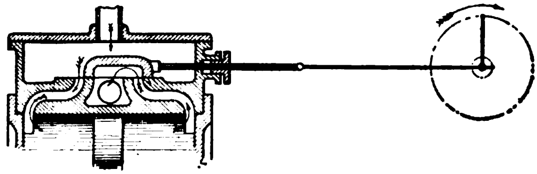


Fig. 8. Elementary Slide Valve.

A steam engine with valve arranged as above would take steam through the entire stroke, and would exhaust at boiler pressure. It would develop the maximum power of which it was capable at that pressure, but no use would have been made of the expansion force of the steam. For this reason, all practical steam engines are made to admit steam only for the first portion of the stroke, *i. e.*, about one-half stroke or less, the remainder of the stroke being devoted to expansion. In Fig. 9, suppose *A* represents the position of a piston moving from left to right. The horizontal distance *B C* represents the stroke, and vertical distances represent steam pressures. *D E* is the line of zero pressure, and *F C* that of atmospheric pressure. Suppose steam is admitted at 50 pounds gauge pressure during the first half of the stroke from *G* to *H;* the steam port then closes and the steam expands with diminishing pressure along the curve *H I*. Since work is the product of force into distance traveled, it follows that for each fraction such as *B J* of the piston travel, the included area *B G K J* will represent the work done during that portion of the stroke, and the area of the entire card *B G H I C* will represent the work done during the whole stroke. In the case under consideration, the area of the whole diagram is 84.4 per cent of that which would have been produced if the steam had entered during the entire stroke, yet only half as much steam is used.

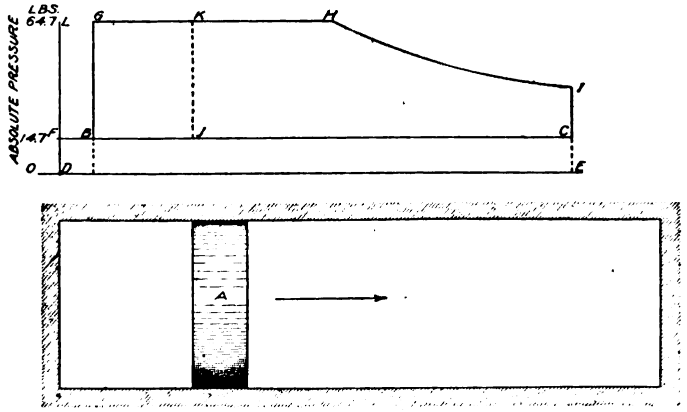
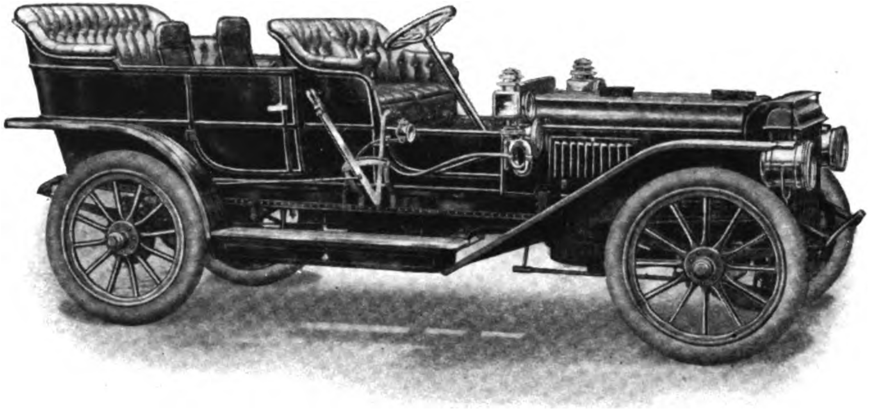


Fig. 9. Theoretical Digram, ½ Cut-Off.

A diagram such as Fig. 9 is called the *indicator diagram* or *indicator card,* and is employed to study the internal action of the



RIGHT SIDE OF LANE STEAMER WITH SEVEN-PASSENGER TOURING-CAR BODY

engine. The expansion curve of steam follows Boyle's Law with sufficient closeness for practical purposes. Fig. 10 is similar to Fig. 9, except that the steam is cut off at one-quarter stroke, point H.

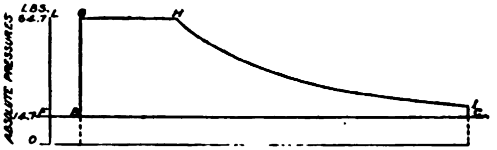


Fig. 10. Theoretical Diagram, ¼ Cut-Off.

In the foregoing, no mention has been made of the contents of the steam passages between the slide valve and the cylinder, or of the clearance volume between the piston and the cylinder head when the crank is on dead center. These clearance spaces cannot wholly be avoided, but it is desirable to reduce them as much as possible. It is customary in indicator cards to represent the clearance space by an area to the left of the actual indicator card. This area is *F L G B* in Fig. 9 and Fig. 10. Its volume averages about 5 per cent of the volume swept by the piston. Owing to the necessity of taking the steam in the clearance space into account, the actual steam consumption in Fig. 10 is a trifle more than half that in Fig. 9.

The objectionable influence of the clearance may be neutralized by closing the exhaust port before the piston has finished its return stroke, thereby trapping the remaining steam at atmospheric pressure and compressing it to boiler pressure. If this is done, none of the entering steam is wasted merely in filling the clearance space. Fig. 11 shows the effect of compression on an actual indicator card. It is not carried to boiler pressure, but only to point *A*.

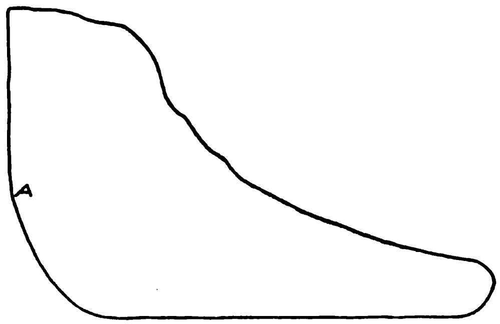


Fig. 11. Actual Card Showing Compression.

Another reason for using compression is to cushion the reciprocating parts at the end of their stroke, and prevent the shock which may otherwise occur on suddenly admitting live steam.

As Fig. 10 shows, no great advantage is gained when working with steam at 50 pounds by cutting off earlier than one-third stroke.

If higher pressure is used, however, the cut-off can be considerably shortened. Fig. 12 is a theoretical indicator diagram for 200 pounds gauge pressure (214.7 absolute). The clearance is five per cent of the piston displacement, and cut-off occurs at one-tenth stroke. The weight of steam per stroke is about the same as in Fig. 10, but the work done by the higher pressure is nearly two-thirds greater. This shows strikingly the economic advantage of using high pressure, provided the cut-off is shortened to correspond.

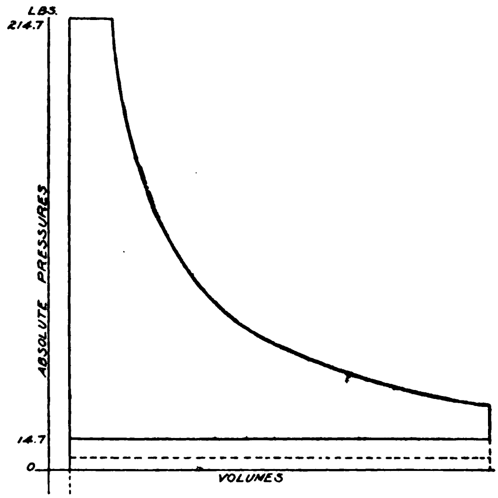


Fig. 12. Theoretical Card, 1/10 Cut-Off.

To produce a short cut-off what is known as *outside lap* or *steam lap* is added to the edges of the slide valve. See *A A* Fig. 13. To produce compression inside, exhaust lap *B B* is also added. Fig. 14 and Fig. 15 show how the valve mechanism is affected by these changes. In Fig. 15 the piston is about to begin its stroke, but the valve is no longer in mid-position. Instead, the eccentric has had to be advanced through an angle, known as the *angle of advance*, in order to open the port as the piston starts to move. The necessary travel is also increased in order to accomplish the idle movement when all ports are closed. As the diagrams show, the valve reaches the end of its movement, returns, and closes the steam port while the piston is in the first quarter of its movement. It then continues to move, but with only the exhaust open.

It is customary, as Fig. 15 shows, to open the steam port a trifle before the piston begins its stroke in order to avoid *wire drawing* of the steam before the port goes fairly open. If this were not done, there would be an appreciable drop in pressure at the beginning of the stroke. The amount of this premature opening of the valve is called its *lead.*

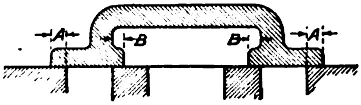


Fig. 13. Steam and Exhaust Lap.

Cylinder Condensation. When steam expands its temperature drops by reason of expansion, following approximately the above table for saturated steam. The effect of this is to cause the cylinder walls to assume an average temperature which slightly increases from contact with the hot steam and slightly diminishes at the end of every stroke. The hot entering steam condenses on the walls, and re-evaporates near the end of the stroke. This is very undesirable, and is avoided by superheating the steam sufficiently to compensate for the initial loss of heat to the walls. In addition, heat loss by radiation is minimized by lagging the cylinder walls and heads with asbestos, magnesia, or other non-conducting coverings.

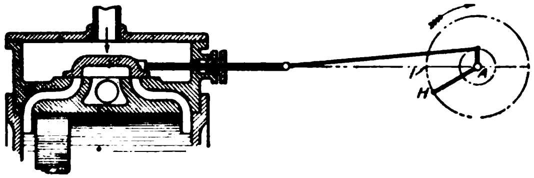


Fig. 14. Valve Action with Lap Added.

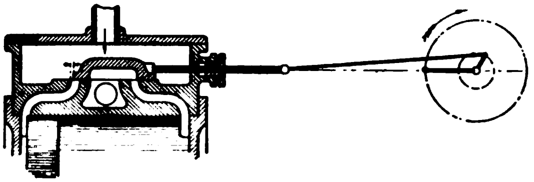


Fig. 15. Valve Action with Lap Added.

When steam is used at pressures above 100 pounds, *compound engines* are preferable, though not always used.

Compound Engines. In a compound engine the work done by expansion is divided as nearly equal as practicable between two cylinders, called respectively the *high-pressure* and *low-pressure cylinders.* The high-pressure cylinder is the smaller in diameter, and it exhausts into the low-pressure cylinder instead of into the atmosphere. In the diagram, Fig. 16, showing the elements of a compound engine, the steam is being transferred from the high-pressure cylinder to the low-pressure cylinder. The steam expands by reason of the difference in the areas of the two pistons.

A compound engine may be considered as though the steam were expanded wholly in the low-pressure cylinder, and the indicator diagrams of the two cylinders may be combined to show the total work done, by shortening the horizontal distances of the high-pressure card in proportion to its smaller piston area.

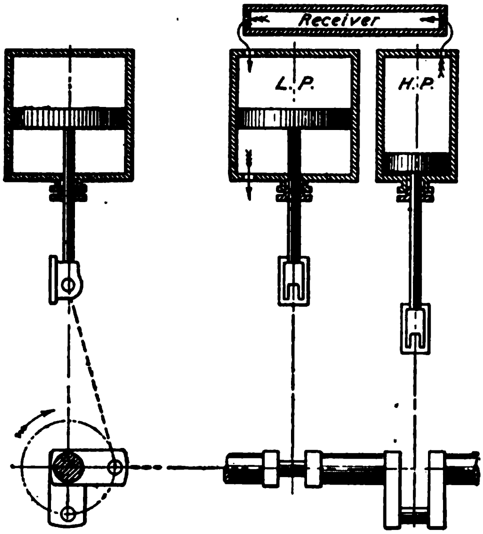


Fig. 16. Elements of Compound Engine.

Fig. 17*a* is a combined diagram from the high- and low-pressure cylinders of a stationary compound engine. Both cards are drawn to the same scale as regards stroke, but the low-pressure card reads from right to left. *F* is the point of admission to the high-pressure cylinder. The slight peak at *A* is due to the inertia of the in-rushing steam. At *B* the admission valve closes. At *C* the steam is released and goes into the receiver between the cylinders. *D E* is the exhaust line, and *E F* the compression line. From *D* to *E* steam passes from the high- to the low-pressure cylinder, the difference between the two lines being due to frictional resistance of the passages. At *G* the exhaust valve opens. *H I* is the compression line of the low-pressure cylinder.

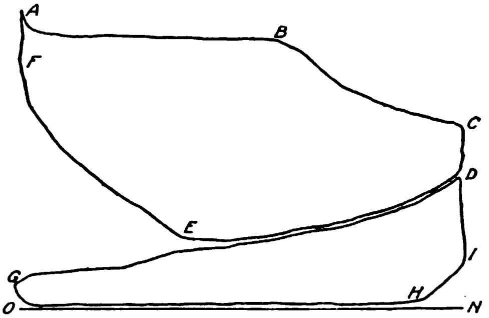


Fig. 17a. Indicator Diagram of a Stationary Compound.

Fig. 17*b* is a combined high- and low-pressure diagram from the engine of the White steam car. In this diagram the low-pressure stroke is shown lengthened in proportion to the piston area so that the high- and low-pressure cards afford true indications of the relative work done in the cylinders.

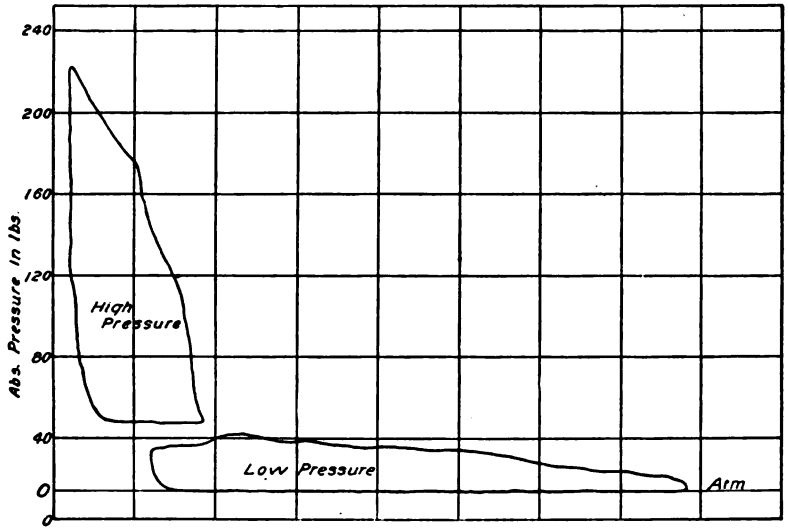


Fig. 17b. Indicator Diagram of a White Compound Engine.

Condensers. In the foregoing paragraphs steam is supposed to be exhausted at atmospheric pressure. In other words, the steam in the working end of the cylinder must overcome a back pressure of 14.7 pounds per square inch in the exhaust end. If the exhaust steam were discharged into a closed vessel and condensed, a vacuum would be formed containing only water vapor at a pressure proportionate to its temperature. (See Table of Saturated Steam). Evidently, a great part of the back pressure would thereby be eliminated, and five, ten, or even twelve pounds might be added to the height of the indicator card with no further expenditure of heat. This result may be accomplished by an apparatus called a *condenser*, consisting usually of a series of tubes cooled by water circulating outside of them. The water of condensation, together with the air carried through the engine with the steam, is removed continuously from the condenser by a suitable pump, called the *air pump.*

It has not been found practicable in automobile service to employ vacuum condensers. In some cars the exhaust steam is condensed, but only to avert the necessity for frequent stops for water. In other automobiles, no condenser is used and the engine is not even compound, sole reliance for economy being placed on superheating and a moderately short cut-off.

Throttling and Reversing. Steam engines are regulated partly by the cut-off and partly by throttling. As has been pointed out above, it is impracticable to use a cut-off so short as to expand the steam to or below exhaust pressure. Beyond this point reduction of power must be had by throttling the steam on its way to the engine.

Stephenson Link Motion. A steam engine may be reversed either by shifting the angular position of the eccentric on the crank shaft by the use of a mechanism known as the *Stephenson link motion,* shown in Fig. 26. A pair of eccentrics on the crank shaft—one for the forward motion, the other for the reverse—by means of the eccentric rods operate a curved slotted link *A* in which works a block pivoted to the end of the valve stem. The link is controlled so as to cause one or the other eccentric to be operative by connecting it to a strap pivoted to the end of an arm, which is latched in the position corresponding to the direction desired.

It is a feature of the Stephenson link motion that by rocking the link toward (but not to) its mid-position the valve travel and cut-off are shortened, and this feature is utilized to improve economy. At the same time the lead is increased, *i. e.*, steam is admitted before the piston begins its new stroke. This is not a disadvantage at high speeds, as the fresh steam has a cushioned effect on the reciprocating parts. At low speeds, however, the engine runs jerkily, and consequently the cut-off is shortened, except at medium to high speeds.

The reason for the comparative non-use of speed changing gears in steam cars is found in the fact that the steam engine, unlike the gasoline engine, works most economically on a fraction of its full load, *i. e.*, with short cut-off. Its power can at any moment be increased by lengthening the cut-off. This, of course, sacrifices economy, but is preferable to the complication of gear shifting.

FUELS AND BURNERS

Gasoline and Kerosene. Gasoline and kerosene are hydrocarbons—*i. e.*, compounds of hydrogen and carbon—derived from crude petroleum, and having certain characteristics in common. Neither of them is a single homogeneous substance. Each is a mixture of numerous similar compounds varying slightly in chemical composition, and likewise in density, volatility, etc. Either of them, if heat be applied, will evaporate fractionally, the lighter constituents first.

To steam users, the most important difference between the two fuels is that gasoline evaporates freely at ordinary atmospheric temperatures, and must be kept under ground or in sealed cans, whereas kerosene evaporates quite slowly in the air, and for rapid evaporation requires the application of heat. Both are inflammable, though the liquid itself does not burn, but only the vapor rising from it. The vapor of either if mixed in suitable proportions with air is explosive. The vapor may be ignited by a flame, an electric spark, or incandescent metal. A smouldering match or a cigar will not usually ignite the vapor, though exceptions to this rule have been recorded.

When hydrocarbon vapor burns in air, the products of combustion are carbon dioxide gas, CO_2, and water vapor, H_2O, to which is added the inert nitrogen of the air, the hydrogen and carbon molecules uniting with the oxygen molecules of the air. It follows, therefore, that the pure vapor unmingled with air is not explosive but will burn only as it finds oxygen to support combustion, and the oxygen must be present in sufficient quantities. A mixture very weak in oxygen will not burn or explode, and the same is true if the air is greatly in excess. A tank full of gasoline will not explode if a match is touched to its open mouth, but the vapor at the mouth will ignite. If, however, the gasoline is rapidly drawn off, air will enter to take its place, forming an explosive mixture. If the vapor of either fuel be subjected to a sufficiently high temperature it undergoes a chemical change by which a part of the carbon is set free, and the remainder with the hydrogen forms a fixed gas which does not condense at ordinary temperatures. If either gasoline or kerosene vapor be drawn through a red hot iron pipe, the pipe will be coated inside with carbon, and eventually clogged solid.

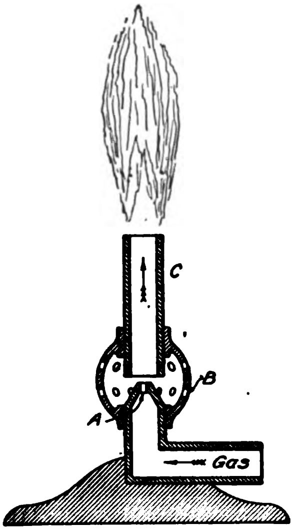


Fig. 18. Simple Bunsen Burner.

Burner Principles. The burners of steam vehicles are similar in principle to the ordinary gas Bunsen burner, Fig. 18. In this burner gas under moderate pressure issues from the orifice *A*, and entrains with it a certain amount of air, which, entering the aperture *B*, ascends with the gas stream, mingling therewith and burning in a pale blue, almost colorless flame at the top of the mixing tube *C*.

The simple form of burner just described is not adequate for steam vehicles. Combustion is too slow, and the temperature is too low. In order to develop a high temperature the combustion must be very rapid; this requires intimate mixture of the vapor and air. Such a mixture is produced partly by giving the gas and air ample time to mingle, and partly by injecting the gas under considerable pressure. To diffuse the gas still more thoroughly, it may issue through several orifices instead of one. The effect of the pressure and subdivision of the gas streams is to draw in air at high velocity. The flame is also short, considering the quantity of gas burned. The more thoroughly the gas and air are mingled, the more quickly they will burn, and the shorter and hotter will be the flame.

Types of Burners. *Stanley.* In the Stanley burner, Fig. 19, there are two separate *mixing tubes* side by side, each of which feeds half the burner. The fuel passes through the *vaporizing tubes A A* leading to the injector nozzles, and it issues from the nozzles as a hot gas, drawing air with it into the mixing tubes *B B*. The *top plate* of the burner is of cast iron and has thin slots across the ridges from which the combustible mixture issues. All the air needed for combustion is taken into the mixing tubes. The flames are prevented from striking back into the *mixing chamber* under the cast-iron plate by the fact that the plate is kept cool by the entering mixture. If the slots were wide the flame might pass through, but owing to the narrowness of the slots any flame entering them is cooled and extinguished. The top plate is of cast iron, for the reason that sheet metal in ordinary forms has been found to warp and scale from the heat.

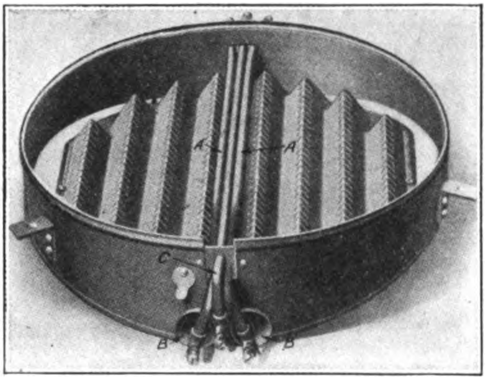


Fig. 19. Stanley Burner.

White. The White burner is similar in principle to the Stanley. The corrugations in the cast-iron top plate are circular instead of straight, and only one mixing tube is employed. The burner nozzle in the later types has three orifices, whose size depends on whether gasoline or kerosene is to be the fuel. The opening of the mixing tube is adjustable to regulate the amount of air taken in. With kerosene, which is the regular fuel in the 1910 White cars, a larger air opening is required than for gasoline.

Lane. The Lane burner, Fig. 20, is made entirely of steel tubing, a large mixing tube delivering gas and air to lateral steel tubes closed at their outer ends. Both the mixing tube and the lateral tubes are drilled with small holes from which the mixture escapes.

The Lane burners differs from the above in taking additional air through the spaces between the cross tubes. In other words, the mixture as it issues from the pin holes is over-rich.

The Pilot Light. An essential feature of the steam vehicle burner is the *pilot light.* This is a small Bunsen flame supplied from a separate vaporizing tube *C,* Fig. 19, and so placed as to keep the main vaporizer hot, regardless of the condition of the main fire. In most steam vehicles the supply of fuel to the main fire is under automatic control, and is reduced or extinguished at frequent intervals when the engine is not developing its full power. The pilot light serves both to keep the supply of fuel hot while the main fire is extinguished, and to re-light the main fire when the fuel valve is opened. In some systems the main fire may be automatically turned on and off several times a minute.

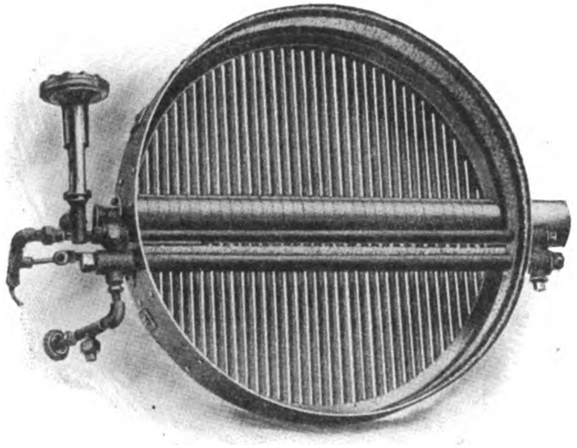


Fig. 20. Lane Burner.

Management of the Burner. To start up, liquid fuel is admitted through a special valve to a cup at the base of the pilot light burner, on the principle that a plumber's torch is heated up. When this fuel is nearly consumed, the regular pilot light is opened. In three or four minutes the vaporizer is hot and the main burner valve may be opened. When a steam car is to stand for some minutes, the main fire is always shut off either by hand or automatically; the pilot light then contributes toward maintaining steam pressure till the car is to be started, but it is not hot enough to prevent slow loss of pressure. At the end of the run the pilot light is separately extinguished.

In the 1910 White cars, the pilot light takes gasoline from a small tank independent of the main tank, which carries kerosene. The pilot light, although burning continuously, consumes very little gasoline, and the small tank does not often have to be refilled.

The pressure necessary for the fuel supply of a steam car is obtained by pumping air into the tank. A power air pump is connected to the engine for this purpose, and is put in or out of action by manipulating a valve or otherwise. When the fuel tank is refilled, the air pressure must be pumped up by hand, unless special arrangements are made. The White kerosene car, for example, has a special hand-operated *warming up* valve in the gasoline line. This valve may be used to raise steam for running the engine free if the kerosene tank has just been refilled, thereby pumping up pressure in the latter.

In the Stanley car an *auxiliary tank* is used, through which gasoline is forced from the main tank by a pump on its way to the main burner. The pressure is maintained in the auxiliary tank only, and fresh air has to be pumped in by hand only to take the place of that absorbed by the liquid gasoline passing through. Thus the main fuel tank is not subjected to pressure as it is in other makes of steam cars.

FIRE-TUBE BOILERS

The simplest form of fire-tube boiler, illustrated in Fig. 21, shows the Stanley boiler *lagged* with asbestos. It is packed full of steel tubes $\frac{8}{8}\frac{3}{4}$ inch outside diameter, which run through from top to bottom and have their ends expanded into the boiler heads. The flames and hot gases pass up through these tubes. The boiler shell and lower head are pressed in one piece from sheet steel, and the upper head is riveted in. The shell is tightly wound with piano wire, the strength of which is far in excess of boiler steel, making the boiler very strong for its weight, and not liable to rupture.

In every steam boiler the upper space is reserved for steam to give the water spray a chance to separate. In the type of boiler just described the steam space is approximately the upper third of the boiler. As the fire tubes in this space are hot, they tend to evaporate any water which strikes them. To ensure further that the steam shall contain no water when it reaches the engine, it is superheated by passing through a pipe, which is carried down through the boiler and forms a flat coil in the hottest part of the fire.

To protect the boiler from damage due to the water level becoming too low, it is fitted with a *fusible plug*. This is a lead plug clamped in a suitable brass fitting which is screwed into the boiler a few inches above the bottom. The plug is exposed to the heat of the fire, but is normally kept from melting by being in contact with the water in the boiler. When, however, the water level gets below the fusible plug the steam can no longer keep it cool, and it *blows out*. The noise of escaping steam gives warning to the operator to shut off his fire and refill. To facilitate this process a valve between the plug and the boiler is closed to check the escape of steam and water.

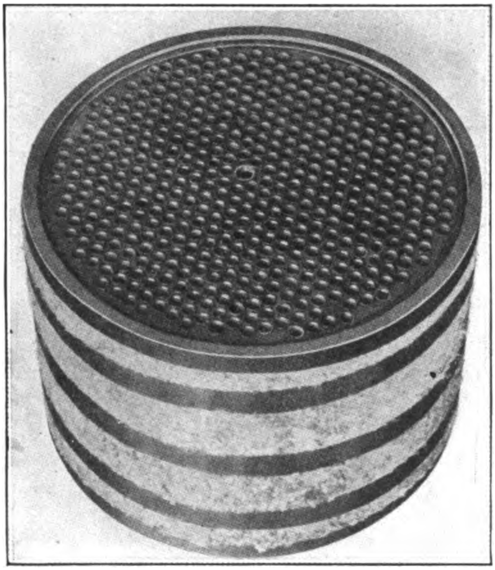


Fig. 21. Stanley Boiler.

Unequal expansion, due to warping or the like, will loosen the tubes and cause leakage. Such warping inevitably follows if the boiler is allowed to get dry, or if the burner is negligently fired up without water in the boiler. Aside from the risk of permanent damage from this cause, it is a tedious and troublesome job to re-expand the tubes. No rule imposed on the steam car owner is more stringent than to satisfy himself at all times beyond peradventure that his boiler has water and enough of it.

The Lane boiler, Fig. 22, combines some features of the fire-tube type with those of the flash generator described in detail on Page 69. Above the boiler proper, which is of the fire-tube type with very large tubes, is a set of coils of brass tubing, brass being used because it is removed from the most intense heat of the fire. The water is pumped into the topmost coil and passes in succession through those below, becoming thereby progressively heated by the gases and flame coming up through the fire tubes. From the lowest coil it goes into the boiler proper, being by this time partly converted into steam. The water falls to the bottom of the boiler, and the steam becomes superheated by contact with the hot tubes. By this arrangement the fuel has been made to give up all the heat possible, and pass off at a much lower temperature than that of the steam.

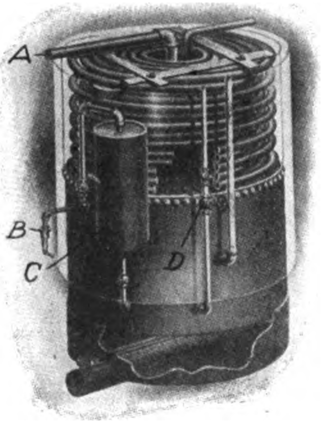


Fig. 22. Lane Boiler.

AUXILIARIES AND CONTROL OF FIRE-TUBE BOILER SYSTEMS

Diaphragm Regulator. In all cars having fire-tube boilers the fire is regulated automatically according to the steam pressure. It is assumed that the water level in the boiler will be maintained substantially constant, either automatically or by hand. It remains then simply to maintain the steam pressure at the proper point. That is done by means of a diaphragm regulator acted on by the steam pressure, and controlling a valve through which the fuel passes to the vaporizer. Fig. 23 shows the *Stanley diaphragm regulator* in section. A diaphragm of sheet bronze or other metal has its edges clamped with gaskets between two portions *A B* of the casing, and a connection at *C* leads to the boiler. The diaphragm bears against a disk *D* backed by a strong spring *E*. The fuel valve, usually of the needle type, is connected to the disk through a guide and stuffing-box *F* as shown, so that when the spring is compressed by the disk bulging under steam pressure the fuel valve will close. The spring is under initial load equal to the normal pressure, and does not respond to the steam till the normal pressure is exceeded. The effect is to cause the fire to be either on or off most of the time, it being found that burners of this type do not operate well when the supply of fuel is considerably reduced but not shut off. The spring tension is adjustable by turning the hollow screw *G*.

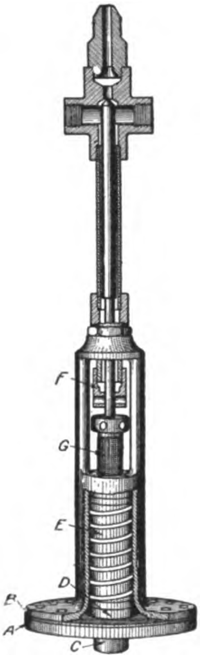


Fig. 23. Stanley Diaphragm Regulator.

Steam Gauge. In all steam cars the pressure in the boiler is indicated by a steam gauge on the dash. Steam does not actually enter this gauge, but pressure is communicated to it through oil which fills the connecting pipe and the gauge itself. The reason for using oil is to prevent freezing in cold weather.

Water Pumps and By-Pass Valve. Water is pumped into the boiler by a power pump, Fig. 24, run from the engine. As this pump runs continuously, a by-pass valve is provided, which, when open, permits the water coming from the pump to return to the pump supply pipe or tank. In some cars, like the Stanley, the by-pass valve is opened and closed by the operator, Fig. 25, according to his observation of the boiler's needs. In the Lane car, an automatic device on the principle of the thermostat controls the by-pass valve, but there is also a hand by-pass valve.

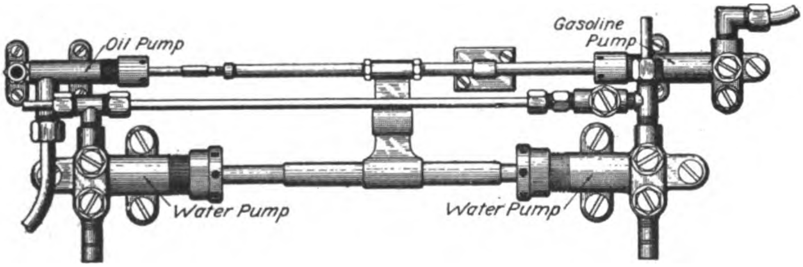


Fig. 24. Power Pumps of Stanley Engine.

In addition to the power water pump, there is always a hand pump, partly for emergency use if the power pump should get out of order, but chiefly to pump water into the boiler when there is no steam up and not sufficient water to make it safe to start the fire. The Lane car has an auxiliary water pump worked by steam.

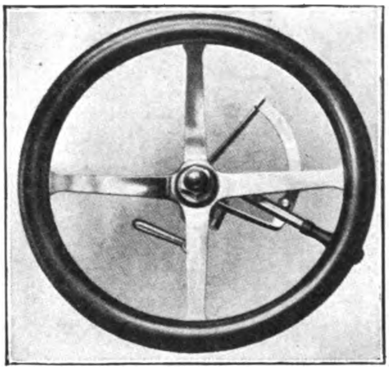


Fig. 25. Stanley Steering Wheel, Throttle, and By-Pass Levers.

Water Level Indicator. In early steam cars a gauge glass of the form commonly used on stationary boilers was employed to indicate the water level. These gauge glasses are unreliable, and with the high pressures now employed are impracticable. In their place is used a thermostat device which depends on the principle that water communicating with the boiler, but cut off from circulation, becomes cold. The general arrangement is shown in Fig. 26. *A* is a pipe leading from the water space of the boiler, *B* is a pipe similarly communicating with the steam space, and *C* is a connection from *A* and *B* to a closed chamber *D* in which

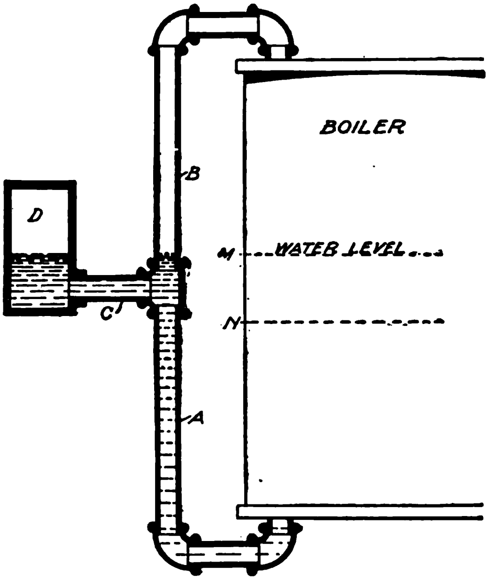


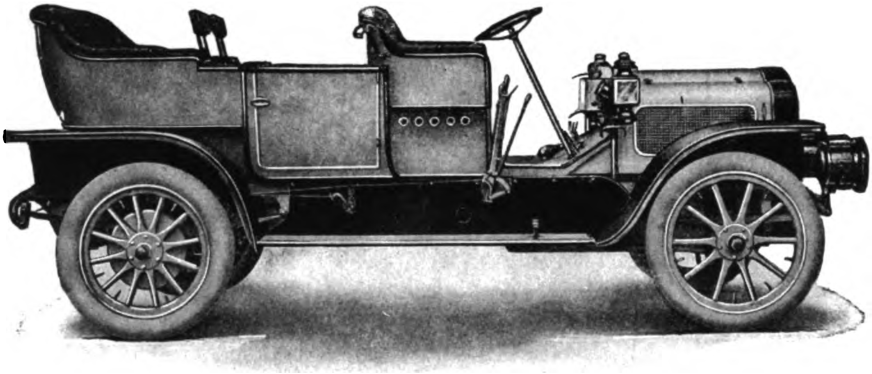
Fig. 26. Principle of Thermostatic Water Level Indicator.

is a thermostat. Suppose the water level is at M: the chamber D will fill with water at boiler pressure. Nevertheless, as this water is not circulating, it will presently become cold, and the thermostat likewise. If now the water level drops to N the chamber D will fill with steam, which as fast as it condenses will settle into connection C. The chamber D and the thermostat will therefore be kept hot by fresh steam. Evidently the thermostat may operate an indicator of any convenient kind whose movement will show whether the thermostat is hot or cold. In the Stanley, the thermostat is simply a copper U-tube partly filled with water, which rises or falls in one end when steam is produced or condensed in the other. In the Lane car, a metallic thermostat is used, which operates by the differential expansion of two dissimilar metals—copper and steel. This thermostat not only controls the water level indicator on the dash, but is likewise connected to the by-pass valve, thereby rendering the latter automatic.

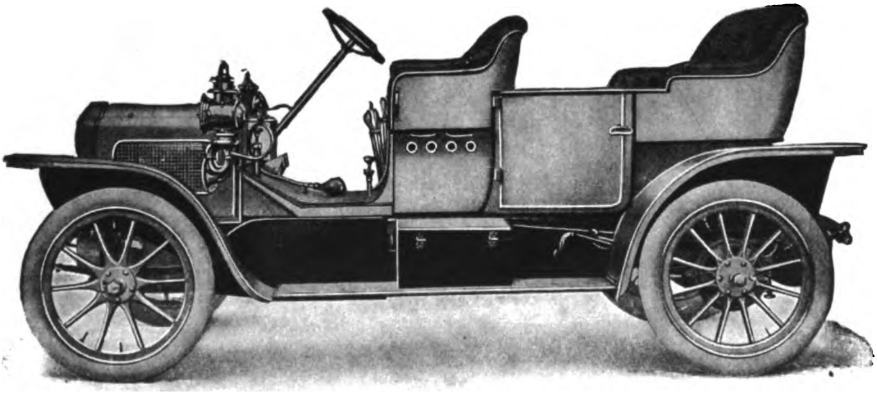
Air Pumps. The power air pump for pumping up fuel pressure has already been mentioned. When the main tank is not under pressure, but only a small auxiliary tank through which the gasoline passes, as in the Stanley, no power air pump is required. A hand pump is always provided for emergency use and for raising pressure to start. The Lane car has also a steam air pump.

Management on the Road. As will be understood from the foregoing, the operator's part in managing the power plant—other than attention to the throttle—is ordinarily limited to watching the water-level indicator, and managing the by-pass valve—if not automatic—in accordance with the water level. When the level drops, the by-pass valve must be closed, thereby causing all the water pumped to enter the boiler. When the water level exceeds the proper height, the by-pass valve is opened, and water ceases to enter the boiler. It is not practicable to open the by-pass valve part way, as this would cause the water to go through the valve at boiler pressure, and in time the scouring action due to the pressure would make the valve leak.

Blind adherence to the above rule will not always give as good results as may be obtained through manipulation. For example, if one sees a hill ahead, he can fill the boiler somewhat higher than its usual level and give the added water time to get hot before the hill is reached. This affords a reserve supply for surmounting the hill. In the average hilly country, one can make a practice of pumping water



STEAM-DRIVEN TOURING CAR, MODEL M 40
The White Company, Cleveland, Ohio.



STEAM-DRIVEN TOURING CAR, MODEL O 20
The White Company, Cleveland, Ohio.

on down grades when little or no steam is being used and the heat of the fire is available to heat the incoming water. Near the bottom of the hills the by-pass valve is opened and the ascent taken in good style. If the accumulated pressure has caused the fire to shut off, the throttle may be opened just before the bottom of the hill is reached, and the drop in pressure will bring the fire on while impetus is being gained. It is a general rule for all classes of steam cars that *the fire should, if possible, be "on" before an up grade is begun.* By proper management the fire may be kept burning continuously in a hilly country, while power is used only on the up grades.

In applying the above principles it should be remembered that only the wetted inside surface of the boiler is available for making steam. If the water is low, steam cannot be raised as rapidly as when the boiler is full, assuming that the water is hot in both cases. On the other hand, if the boiler is worked too full one may get wet steam despite the superheater, with loss of power due to condensation. In an extreme case, enough water might even be carried through to choke the clearance spaces at the cylinder ends. This would probably result in a head being knocked out, or a connecting rod or crank bent, as the water could not be ejected quickly enough by the lifting of the slide valve to save the engine from severe shock when the piston reached the end of its stroke. A boiler of the Lane type, in which the water is partly converted into steam in coils above the boiler proper, and in which the fire tubes are large enough to permit combustion to take place inside of them, is an exception to the above, in that superheating takes place chiefly in the "boiler."

The more rapidly fuel is supplied to the burner, the hotter will be the fire. Where ample power is desired, therefore, the burner is worked under more than ordinary pressure. The normal pressure for the White burner is 50 pounds, although from 35 to 60 or 70 pounds may be carried. In the Stanley cars, which carry pressure only in the auxiliary tank, 100 pounds is recommended. The Lane cars may be worked under 30 to 80 pounds.

CARE AND MANAGEMENT OF FIRE-TUBE BOILER CARS

This section deals in a general way with the principles to be observed in the management and care of all cars having fire-tube boilers. It also gives hints regarding scale prevention, cleaning of water tank, etc., which are applicable also to cars having flash generators. It should therefore be read carefully, no matter what type of car one expects to operate.

Firing Up. As will later be explained, it is customary at the end of a run to *blow down* the boiler, for the purpose of ridding it of whatever sediment may be present. The blow-off valve is shut when a few pounds of pressure still remain, and the condensation of this remaining steam should suck the boiler full of water, *provided* the by-pass valve is closed. The presence of this water is desirable to protect the superheating coil when the fire is started. Therefore if the car has a conventional fire-tube boiler with superheating coil beneath, the first step is to ascertain whether the boiler is actually full. Close the by-pass (if open), open the upper trycock, and if no water comes out, work the hand pump. See that the water tank is full. Open the throttle and the drip valve on the steam chest and continue pumping by hand till water comes out. Leave them open while starting the fire, to allow the water to expand.

If there is no pressure in the fuel tank, pump it up to the minimum working pressure by hand. Admit gasoline to the cup by which the pilot light is heated—the Lane car uses alcohol and a long asbestos "wick"—and light it. When nearly burned out, open the pilot light supply valve slowly. If a blue flame does not result, close the supply valve and admit more gasoline to the cup.

After starting the pilot light, allow it to burn till the vaporizer is hot, then open the main burner valve carefully. If it fires back into the burner, shut it off, wait a minute or two and try again. Turn the burner to full height gradually. If the flame is yellow or smoky, it is not getting enough air; if it is noisy and lifts off the burner, it is getting too much air. Once adjusted for a given fuel pressure, the nozzle or air shutter should not need changing.

While the water is getting hot, the oiling up can be attended to. As soon as the pressure begins to rise, water will issue from the drip cock on the steam chest. Close this cock and the throttle valve as soon as clear steam comes out.

When pressure reaches 100 or 200 pounds, get in the car, throw the reverse lever to its full forward or backward position, open the throttle slightly and close it at once. Repeat till the engine starts. With some yards of clear way, work the reverse lever back and forth with the throttle open only a crack, so that the car "seesaws" slowly. This will work the water out of the engine and warm up the cylinders till the entering steam ceases to condense. This process must not be hurried. An attempt to cut it short is likely to result in damage to the engine. As long as water is present the engine will run jerkily. When it runs smoothly the car is ready to start.

On starting, the first few blocks should be run slowly to complete the warming up process. If the air pressure is below normal the air pump should be kept going.

At the End of a Run. On finishing a run, the boiler should be blown down with the fire turned off. This should be done by opening the blow-off valve near the bottom of the boiler. The escaping water will carry with it whatever mud and precipitate that has accumulated. Close the blow-off valve at about 100 pounds, and the subsequent condensation will fill the boiler by suction from the tank. If the water in the tank is covered with oil, the end of a hose should be inserted and the tank flushed out to get rid of the oil. It is a good plan to put a cupful of kerosene into the tank. It will not only loosen whatever oil may be clinging there, but will help loosen the scale liable to form, from hard water, so that on the next blowing down the boiler will be left clean.

A thermostat water level indicator operates only when steam is up. When the boiler is cold it indicates high water whether water is present or not. When the car is running a faulty reading of the water level is usually soon noticed, and if it is overlooked there is still the protection of the fusible plug. If, however, the boiler should be fired up with no water in it, the fusible plug would melt without the fact being heralded by escaping steam. Therefore the fusible plug, like the water level indicator, is useful only when steam is up.

Lubrication. Steam cylinder oil, which consists of mineral oil mixed with tallow, and sometimes having graphite added, is usually recommended for steam cars. Rarely do the makers recommend straight mineral oil. The oil is fed usually to the steam chest for lubricating the cylinders, and the reason for adding tallow is to cause the oil to cling to the wet cylinder walls, which a straight mineral oil will not do. With superheated steam, however, this is not always necessary. The main bearings, crank pins, and cross heads are lubricated by splash, the crank-case being enclosed for this purpose.

The Fusible Plug. If the fusible plug blows out when the car is running, the escape of steam may be shut off by closing a valve usually interposed between the boiler and the plug. The fire should be shut off at once, and if possible the car should be run to reduce the pressure, thereby allowing the boiler to cool somewhat. When the drop in pressure compels a halt, close the by-pass valve and pump water in by hand till it shows in the lowest trycock. Then, after replacing the fusible plug, the fire may be relighted and the water level restored while the car runs.

If the plug blows simply because the by-pass valve has been open too long, the by-pass can be closed, the main fire shut off, and the engine run by jacking up the rear wheels, till water shows in the lowest trycock.

Causes of Low Pressure. Low pressure is generally due to insufficient fire. If the burner pressure is low, steam will not be made rapidly. If the burner pressure is all right, the burner nozzle may be clogged or the vaporizing tube may be choked with carbon. The nozzle may usually be poked out with a bent wire without turning off the fire. If, however, the vaporizer is clogged it will have to be removed when the car is cold and cleaned with a drill or otherwise, as the makers direct.

Occasionally the valve controlled by the diaphragm regulator may be choked, and rarely the main burner valve. Either can be cleaned by disconnecting and running a wire through.

Occasionally the pilot light may clog in the same way, usually at the nozzle. The remedy is the same as for the main burner.

If the air pump fails to raise the pressure on the fuel tank to the required degree, it is probable that the intake or outlet check valves leak. If, as is likely, they have oil on them the oil may have gathered dust. The valves should be taken out and cleaned, and a drop of oil put on them to make them tight.

The various packings about the engine and auxiliaries require occasional tightening, and once in a while new packing is necessary. If the new packing is soft, *e. g.*, wicking, it may be put on top of the old, otherwise the old must be removed. The packing should not in any case be tighter than necessary to prevent leakage, for an unnecessary friction is thereby caused. A slight leakage about the water and air pumps may be tolerated to save friction. As the hand pumps are rarely used their packings can be looser than those of the power pumps.

Scale Prevention and Remedies. In sections where hard water is used, the subject of scale is a serious one, and its treatment will depend on the character of the mineral contained in the water. Frequently it is possible to precipitate the mineral before putting the water in the tank. Sometimes the addition of a small quantity of lime will do this, sometimes carbonate of soda or "soda ash." Still other waters are successfully treated by adding caustic soda. Sometimes the simple addition of kerosene to untreated water will loosen the scale as above indicated. If these remedies are not successful, the user is advised to send a sample gallon of water to a maker of boiler compounds and have it analyzed, after which a suitable compound can be recommended. Scale allowed to accumulate by neglect is not only very detrimental to the boiler by interfering with the free flow of heat, but it seriously reduces the steaming power as well. Instances have been known of the steaming capacity of boilers being reduced fifty per cent or more by scale. At the same time the shell and tubes get hotter than they should, resulting in unequal expansion and leakage.

OPERATION AND CARE OF STANLEY STEAM CARS

General Description. The leading elements of the Stanley cars have already been mentioned. The fire-tube boiler is located under the hood in front. The engine is simple, double-acting, and has two cylinders, Fig. 27 and Fig. 28. The cylinders and valves are shown in section in Fig. 29. The engine is suspended horizontally just ahead of the rear axle and drives through a spur pinion and gear. A sheet copper casing protects it from dust. Steam is used at 400 pounds pressure with a high degree of superheat. Stephenson link motion is used, and the cut-off is shortened by pressing a pedal which is held in position by a pawl on a notched segment on the engine. Steam is carried to the engine through a flexible steam pipe having a ball-and-socket joint where it connects to the steam chest.

In Fig. 30 is shown the arrangement of the steam and superheating pipes, the throttle valves, and the cylinder oiling mechanism. Steam from the top of the boiler passes immediately through

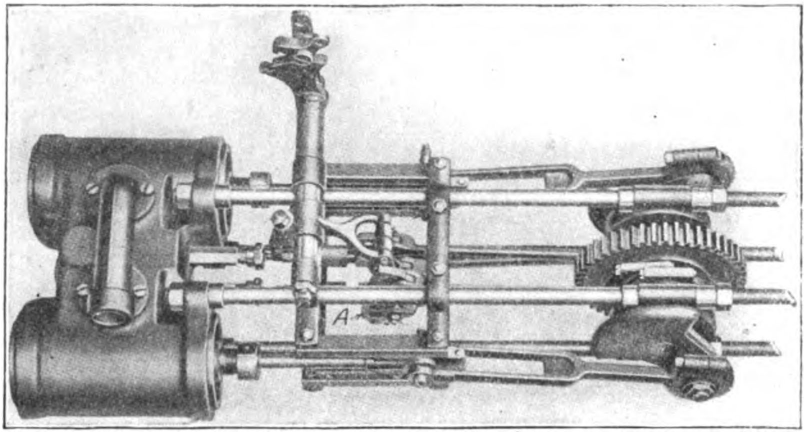


Fig. 27. Stanley Engine, Top View.

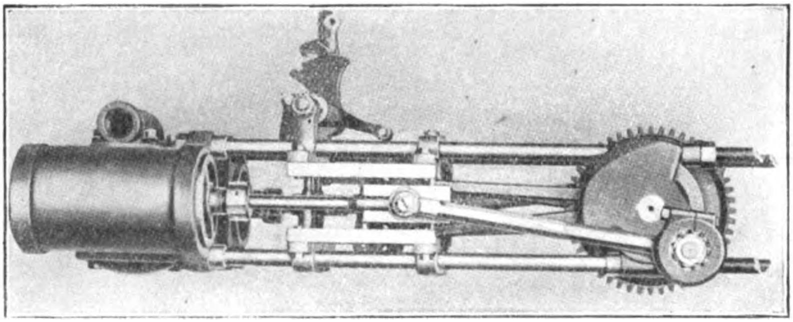


Fig. 28. Stanley Engine, Side View.

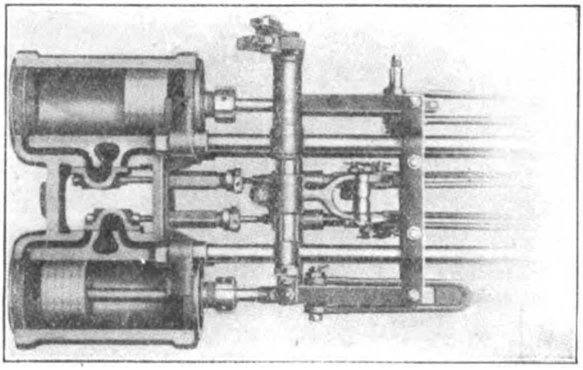


Fig. 29. Stanley Engine, Cylinders and Valves in Section.

the main throttle valve controlled by the operator, and thence to the auxiliary throttle valve. The pipe then divides and the steam passes by two smaller pipes down through the boiler, through the superheated coils, and up again through the boiler to the main steam pipe.

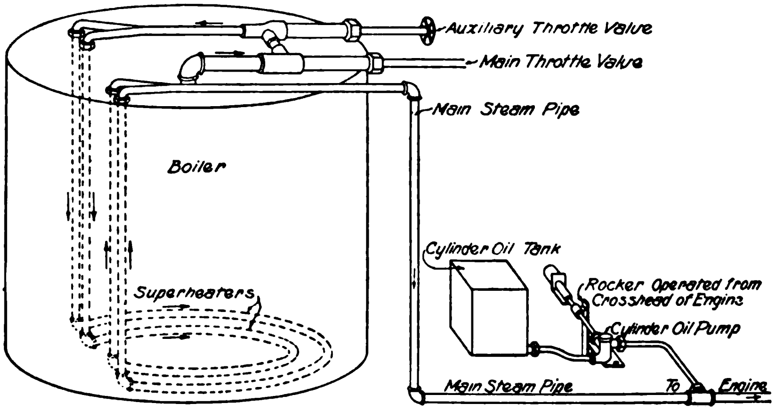


Fig. 30. Steam System of Stanley Cars.

The gasoline system is shown in Fig. 31 and Fig. 32. Instead of using air pressure in the gasoline tank a power pump forces the gasoline to the vaporizer under pressure maintained by a supplementary or pressure tank. An automatic relief valve, Fig. 33, just beyond the power pump, returns the excess gasoline to the tank. A hand gasoline pump is provided for emergency use and for filling the pressure tank when the engine is not running. Of the two pressure tanks, the first, marked 2, is normally filled with gasoline, and the other with compressed air which acts as a cushion. The gasoline does not flow through tank 2, but merely rises and falls in it. The steam automatic, controlling the fire, is shown in Fig. 23. Fig. 34 shows the water system. Two power pumps, Fig. 24, worked from the engine, throw water through the water level indicator, Fig.

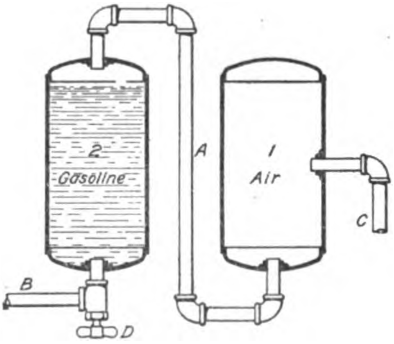


Fig. 31. Gasoline Pressure Tanks of Stanley Cars.

26, into the boiler when the by-pass valve is closed. Opening the by-pass valve causes the water from the pumps to return to the tank. A hand water pump is provided for use when the engine is not running, or when the power pumps fail. To operate the hand pump, the by-pass valve must be closed, and the hand pump valve opened.

Filling the Boiler. Before firing up, be sure that the boiler and superheaters are full. To be sure of this, open the throttle valve and steam chest drip, close the by-pass valve and work the hand pump until water comes from the steam chest drip. If more convenient, fill the boiler from the town supply by means of the coupling furnished for this purpose, connecting to the blow-off valve. Never light the fire until sure that the boiler is full.

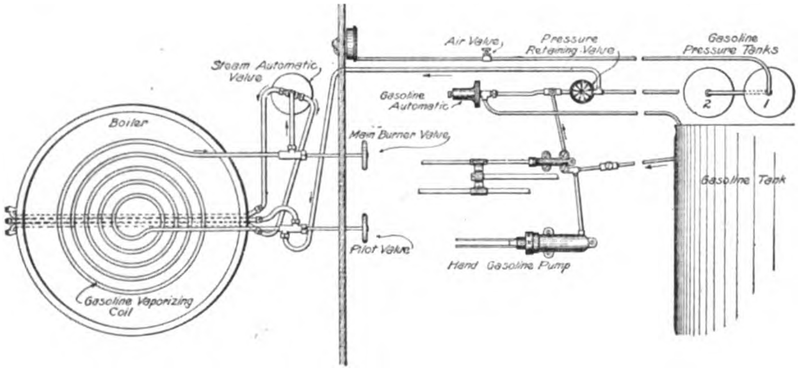


Fig. 32. Gasoline System of Stanley Cars.

At the end of a run open the blow-off valve at the front of the boiler, and blow down to about 100 pounds. Fill the water tank and close the by-pass valve, and the condensing steam in the boiler will siphon the boiler full. Before blowing down, see that the pilot light is out as well as the main burner. It can be extinguished by blowing into the pilot mixing tube.

Raising Gasoline Pressure. If the pressure tanks, Fig. 31, are empty and the pressure zero, proceed as follows:

Open the hand, gasoline pump valve and work the pump till the air gauge registers 10 or 15 pounds. Tank 2 is now full of gasoline, and tank 1 is full of compressed air. Attach the hand air pump to air valve, Fig. 32, and pump air into tank 1 till the gauge indicates 80 or 90 pounds, which is the working pressure for the burner.

If now the fire is lighted and the car stands still, the pressure will gradually drop, but may be raised in a moment by working the hand gasoline pump. When the car runs, the power pump maintains the supply.

The air in tank 1 is gradually absorbed, and additional air is required. This is indicated, first, by the vibration of the air-pressure gauge needle when running; second, by a rapid drop of pressure when the car stands still. In case of doubt whether the drop is due to lack of air or to a leak in the automatic or pump valves, close the pressure retaining valve, Fig. 32. If the pressure still falls the air is insufficient.

Occasionally empty the pressure tank by opening valve *D*, Fig. 31, and refill in order to determine definitely the amount of gasoline in it.

If the car is to stand some time with pilot burning, close the pressure retaining valve to prevent the gasoline from leaking back through the valves and automatic. Be sure to open again on starting.

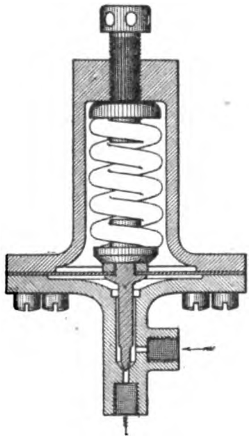


Fig. 33. Gasoline Automatic Valve, Stanley Cars.

Firing Up. The burner and pilot nozzles are heated before starting by a separate gasoline torch furnished with the car.

After the nozzles are thoroughly heated, light the pilot by opening its valve one turn and pointing the torch flame into the sight hole covered by a slide, then close the slide and open the main burner valve very slowly to give the vaporizer time to heat.

The throttle valve and drip valve, which were opened when filling the boiler, should stay open while firing up. Close the throttle at 20 or 30 pounds, lest the car should run away; then open the blow-off valve and leave it open till the boiler is about three-quarters full.

It is best to start with about 200 pounds pressure and work up by degrees, as there is then less risk of damaging the engine by water.

Always start the car with the steam chest valve open to allow water of condensation to escape. Run the car back and forth slowly till the engine runs smoothly, then close the steam chest drip valve. Immediately before starting out open the main burner valve wide, *i. e.*, one or two full turns.

If the boiler is under a hood in front, raise the hood when firing up.

Cylinder Lubrication. It is essential to keep the engine oiler constantly supplied. This oiler works automatically and the oil tank should never become dry. Should this happen the pump will become air bound and must be primed by disconnecting the oil pipe leading to the steam pipe, and working the pump by hand till oil comes out. Use nothing but the best superheat steam cylinder oil.

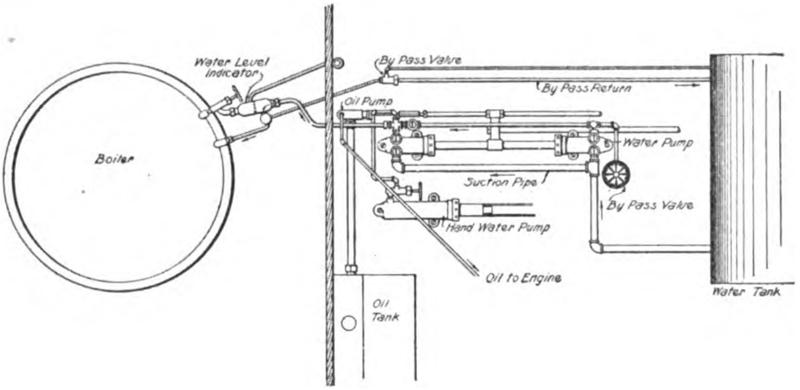


Fig. 34. Water System—Stanley Cars.

General Lubrication. All the bearings of the engine pumps and rear axle should be oiled at least once a day. Steam cylinder oil is suitable and is most readily applied by an oil gun. To oil the eccentrics, squirt the oil into the top of the engine case between the eccentrics, and it will run down over them and into the ball races. The steering gear should be oiled about every two hundred miles.

Glass Water Level Indicator. The Stanley water system, Fig. 34, is controlled by a water level indicator which works on the thermostatic principle explained on Page 31. A casting, of the sectional form shown in Fig. 35, is located between the boiler and the dashboard, and about at the normal water level. It is partitioned into two parts, marked *water chamber* and *boiler chamber*, Fig. 36. Through the former flows the water from the pumps, entering at the top and going out below to the boiler. Another outlet goes to the by-pass valve, so that the cold water flows through the water chamber whenever the engine runs. The other side, or boiler chamber, communicates through *D*, Fig. 36, with pipes leading to the steam and water spaces of the boiler. If the water level is above *D* the boiler chamber is filled with water, which soon cools. If the water level is below *D* the boiler chamber is filled with steam. Into the boiler chamber projects one end of a U-shaped copper tube closed at that end, and at its other end communicating with a sealed water glass on the dashboard. This tube has its front end filled with water, and its dashboard end filled up to about the level shown. When the front end is heated by the surrounding steam, steam is formed in it, whose expansion forces up the water in the glass. When the steam condenses, the water comes down again. Consequently low water in the glass indicates high water in the boiler, and high water in the glass indicates low water in the boiler.

When the car is standing, the indicator may receive heat enough to send the water up in the glass, regardless of the level in the boiler. If, however, the boiler level is high the water in the glass will soon drop when the boiler chamber is cooled off by running the car.

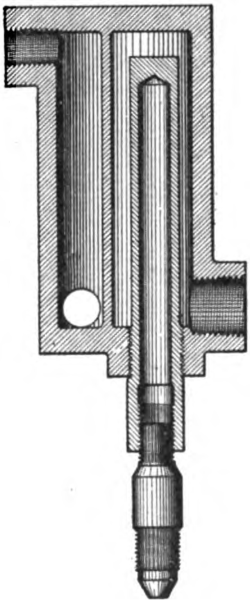


Fig. 35. Water Level Indicator.

Beside the water indicator, there is a low water trycock on the dash, and a blow-off cock *A*, Fig. 36. In using the former, hold it open long enough to be sure that the water issuing is not simply water of condensation lodged in the trycock.

Should some of the water evaporate out of the water glass, it must be replenished. If the U-tube is disconnected for this purpose, great care must be taken that the front end of the U-tube, called the *stand pipe*, has no air admitted to it, since otherwise it would not operate. Ordinarily it is not customary to disconnect the U-tube at the stand pipe, but only at the water glass end. If the stand pipe needs filling, disconnect both unions on the U-tube, unscrew the stand pipe, turn it upside down, unscrew the union stub end, and after filling replace the union stub end—the hole in the latter is so small that the water will not run out. After filling the water glass, loosen the union at the base of the stand pipe and let water escape till it is about an inch from the bottom of the glass, then tighten up the union. This will allow any air in the vertical part of the copper tube to escape, and insure its being full of water.

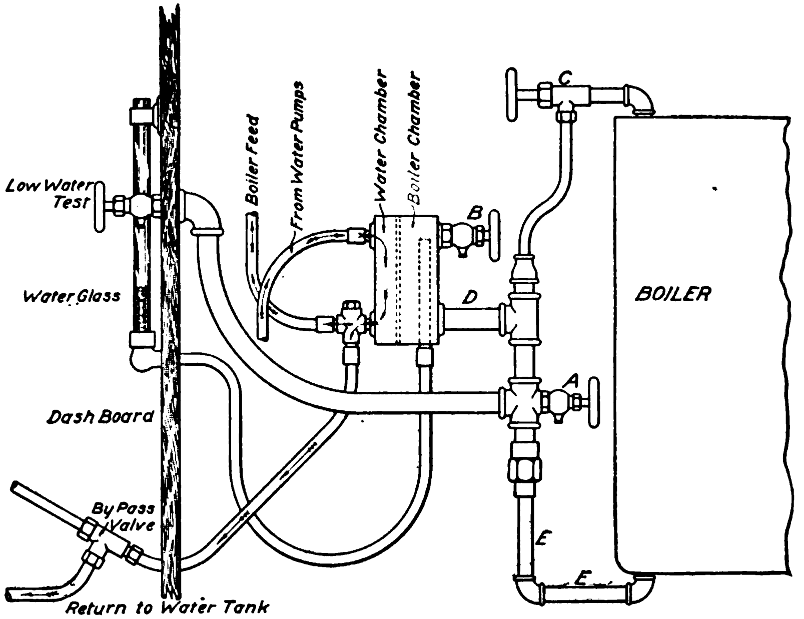


Fig. 36. Water Level Indicator in Section.

See that the water glass is cushioned by the rubber tube provided for the purpose at its upper end.

Do not shorten the U-tube. It must extend several inches below the stand pipe to prevent steam from getting into the water glass. The water level indicator only operates when the car runs. Do not depend on it to show the water level, when firing up, but proceed as directed on Page 41.

Sediment in pipes *E E* will render the water level indicator inoperative. Use the blow-off cock *A* occasionally with valve *C* shut.

To test the indicator, open petcock *B*, with boiler hot and the car standing still. The boiler chamber will heat up and water will rise in the glass. Close petcock *B*, then open the by-pass, and work the hand pump. The water should fall in the glass.

In winter to prevent freezing, use a mixture of water and glycerine or alcohol, equal parts, in the U-tube.

Fusible Plug. The fusible plug is located in front, 3 inches above the bottom of the boiler. In the later Stanley cars, after shutting off the main burner and pilot, the escape of steam can be checked by screwing a shut-off valve stem into the fusible plug fitting. If possible, keep on running to cool the boiler, then close the by-pass, and pump water by hand till the plug is cool enough to be handled. Time is saved by keeping on hand one or more tubes with the lead fitted. When water comes from the blow-off cock the fire may be relighted—usually it is not necessary to use the torch.

If the low water is due simply to neglect to close the by-pass valve, the by-pass may be closed, the pilot lighted, and the engine run with the rear wheels jacked up till water comes from the trycock.

The superheating tubes and the fusible plug fitting are driven into place and held by friction. To start them, hammer them sidewise, prying at the same time.

Water Pump. If the water pump fails to work, first see if the tank is empty. Other than this there are three principal causes of failure, viz: (1) *The pump may be air-bound.* To remedy, simply open the by-pass valve and run. The air will work out readily since there is no pressure against it. (2) *The check valves may leak.* There are three check valves, one on the pump intake, another on the outlet, and the third at the boiler. The intake valve is the most likely to leak. Remove the valve cap and clean the valve ball and its seat, being careful not to scratch them. If the boiler check valve should leak, it would permit steam to escape into the water tank when the by-pass valve was open. This valve can only be examined when there is no pressure. (3) *The pump packing may leak.* Tightening the packing nut generally suffices, but occasionally repacking is necessary. Do not screw the packing nut tighter than is necessary, as it causes needless friction; a slight leakage may be tolerated. In case the power pump fails, use the hand pump, first running with the main fire off till the pressure is reduced to about 100 pounds. After pumping, close the valve with the pump plunger in.

Gasoline Pump. In most respects the gasoline pump resembles the water pump. If it becomes air bound, it can be primed by using the hand gasoline pump, which is much larger, and, drawing through the power pump, will suck out the air.

The gasoline pump packing should not leak at all, as it is both wasteful and dangerous. The pump is so small that adjusting is seldom needed.

If the hand gasoline pump becomes air bound, unscrew the valve which is open when the hand pump is used till it comes out. Press the thumb over the valve stem hole when the pump plunger is pulled out, and lift it off when the plunger is forced in. Repeating this several times will expel the air.

If the hand gasoline pump and hand water pump work together, the packing nut on the gasoline pump should be just tight enough to hold the gasoline, and the water pump should have its packing so adjusted that the pump will run perfectly free.

To pack the gasoline pump, first put in a thin leather washer, then three of the special packing rings supplied by the makers, then another thin leather washer, and screw the stuffing-box nut only hand tight. Do not use a tool to tighten it, otherwise the plunger will cut out the packing.

Care of Engine Bearings. If the engine is regularly lubricated the bearings will seldom require adjustment. If the bearings show the slightest discoloration from rust they have been insufficiently oiled. Adjustments are made as follows:

The crosshead guides are taken up by screwing down the nut on the bolt holding the frame rods together. The crosshead balls must be under sufficient pressure to keep them from slipping.

The wrist pins are taper and are adjusted with a screw held by a lock nut. First loosen the lock nut, turn up the screw till it stops, then back it one-eighth turn and tighten the lock nut.

The crank-pin ball bearings are adjusted by removing the bolt, taking out the plug, and reducing it slightly by filing. When correctly adjusted the bearing should have no perceptible play.

The main bearings and eccentrics can only be adjusted after the engine is taken out of the car. They are adjusted to take up lost motion by filing or grinding down the face of the bearing cap, which must be very carefully done.

Be sure the engine frame hangers are properly adjusted. Should the nuts work loose, the front end of the engine will sway, to the damage of the engine case and gears. In adjusting the engine frame hangers do not set them up so tight that they will not swivel around the rear axle. If necessary insert shims of paper or thin brass, removing the rear engine case to gain access.

Operating the Cut-Off and Reverse. In the more recent Stanley cars the cut-off is variable from one-quarter to one-half stroke. On the engine is a quadrant from which the reverse lever works in connection with the reverse pedal. The quadrant has one notch into which drops a dog attached to the reverse lever when the engine is "hooked up," *i. e.*, operating on short cut-off. To hook up the engine, press on the reverse pedal only. To release the dog, press a pedal beside the reverse pedal, called the *clutch pedal.* This releases the reverse pedal and a spring pulls it back, allowing the engine to cut off at half stroke. The car should always be started with the reverse pedal released, and the cut-off should not be shortened till the engine attains good speed. If it operates jerkily, release the reverse pedal by pressing the clutch pedal.

Care of the Burner. If the car does not steam well, look at the fire first. See that the gasoline pressure is not below 100 pounds.

If the pressure is right, the gasoline line may be clogged in the automatic valve, vaporizer, burner nozzle, or main burner valve. If the burner has two mixing tubes, as in the illustrations, see if both sides are affected; if so, the trouble is likely to be in the automatic valve. If the two burner flames are unequal, the trouble may be in the vaporizing tubes or the nozzle, more likely the latter. Clean the nozzles by running a small wire through them with the screw out, or by using a bent wire without removing the screw.

If the vaporizing tubes are clogged, uncouple at the back of the burner, take out the bundle of wires from the tubes, and clean the tubes and wires thoroughly, using the bundle as a swab. Extinguish all fire before beginning.

If the pilot light nozzle becomes clogged, use a screw driver to turn the horizontal nozzle screw back and forth. A wire projects from this screw, through the nozzle orifice, and turning the screw causes the wire to clean the nozzle. Do this only with the pilot burning.

To regulate the air received by the pilot, bend the pilot vaporizer tube slightly away from the mixing tube for more air, or inward for less air. The pilot should burn with a blue flame slightly tinged with yellow, and may be adjusted while lighted.

Never use a reamer for cleaning either the pilot or main burner nozzle, as it is likely to enlarge the hole.

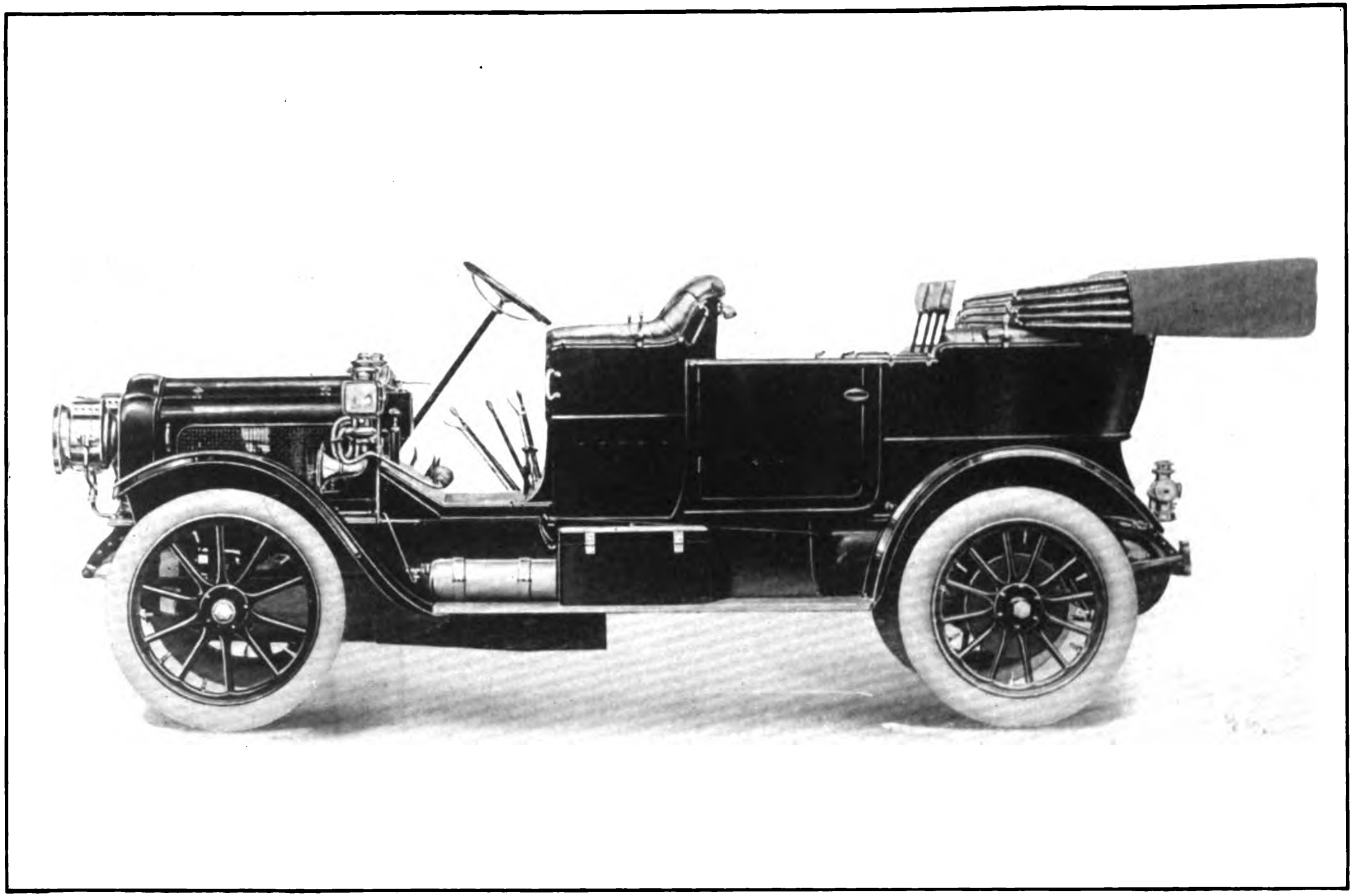
Sometimes after the automatic valve closes, the gas pressure at the nozzles will reduce gradually, causing the burner to light back. When next the automatic valve opens, the fire will burn inside the mixing tubes with a roaring sound. This sound should be the instant signal for closing the main burner valve, and allowing the mixing tube to cool.

If the burner should fire back frequently and with a sharp explosion, it would indicate either a leak in the burner or a leak of steam in the combustion space. To test for a steam leak, first get up steam pressure, then take off the burner and examine the boiler, then run the front wheels against something immovable and open the throttle valve to see if steam escapes from the superheaters.

To Adjust the Throttle. If the throttle valve leaks it must be reground or a new valve substituted. It may, however, appear to leak owing to improper adjustment. There should be some tension on the valve stem when the lever is locked in the closed position. There is a distance rod running from the body of the throttle valve through the dashboard close to the throttle valve stem. To increase the tension on the throttle, adjust the nuts on the distance rod.

To Adjust the Automatics. To carry a higher steam pressure, screw the adjusting screw on the automatic valve further in; for a lower pressure, screw it out. The same regulation of the gasoline relief valve will produce similar variations of the fuel pressure.

To Lay Up for the Winter. Run the car on the road or with the rear wheels jacked up till everything is hot, then extinguish the fire and blow off the boiler. While steam is escaping, open the safety valve and siphon valve and take out the fusible plug to clear them of water. Empty the tank, take off the caps of the check valves, and blow into the suction holes to clear the water from the checks



WHITE MODEL MM STEAMER
With a Seven-Passenger Body.

ahead. Take off the water indicator and empty it unless it is filled with non-freezing mixture.

General Remarks on Operating. The commonest fault of Stanley operators is opening the throttle too abruptly on starting. This is bad enough if the cylinders happen to be clear of water: if they are not clear the results may be destructive. Always start slowly, and do not come up to road speed till the engine runs smoothly.

Never open any of the valves more than two or three full turns. They are screw valves, and if turned a dozen or more times they will come clear out.

Practice reversing where you have plenty of room. The ability to look and steer backward while operating the reverse pedal and throttle is not a natural gift. After reversing, be sure that the pedal has been released by pressing the clutch pedal before giving steam.

Never reverse when going up hill. Keep on going till you reach the top.

OPERATION AND CARE OF LANE STEAM CARS

The Lane steam boiler and burner have already been described. The engine, Fig. 37, is a cross-compound with Stephenson link motion and simpling device on the back of the steam chests. The simpling device, Fig. 38, which is operated by a foot plunger, consists of a plug valve in a cylinder screwed into the back of the steam chests. By suitably turning this valve, high-pressure steam is admitted to both steam chests for starting. The Lane chassis is shown in plan and elevation in Fig. 39 and Fig. 40.

The fuel tank is under air pressure maintained by a power air pump on the left side of the engine, supplemented by an auxiliary steam air pump and hand air pump. Both the air and water pumps are inside the engine casing with their plungers directly actuated by the crossheads. The fire is regulated by a diaphragm automatic valve, and the by-pass is controlled by a thermostatic device supplemented by an independent, hand-operated by-pass controlled from the steering wheel, Fig. 41.

Firing Up. See that there is water in the tank, also that the level in the boiler is up to the lower trycock on the right side, Fig. 22. If the boiler is too full, open blow-off valve *A*, Fig. 42. To vent the boiler, open the forced draft valve on the steering column.

See that the gasoline tank is filled—filling cap is under left front seat—and the air pressure is pumped up. To fill the tank, first close the air valve *D*, Fig. 43, to retain the pressure in the auxiliary air tank before unscrewing the filler cap. Unscrew filling cap slowly when there is air pressure. Fill the tank entirely full; it then requires little pumping to raise the pressure. Use gasoline only, not benzine or kerosene.

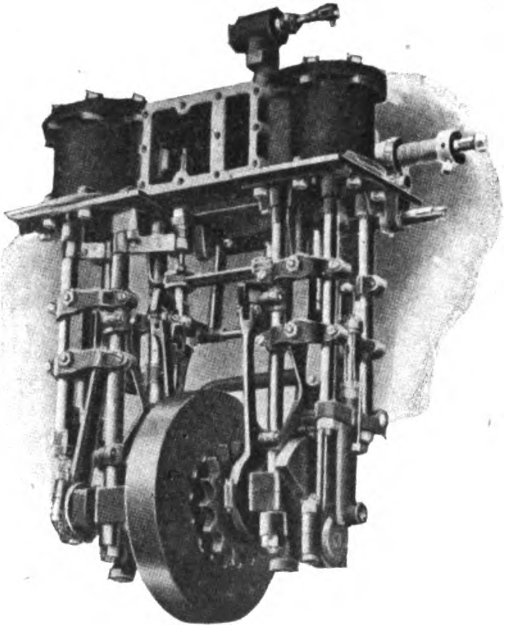


Fig. 37. Lane Engine, with Oil Case Removed.

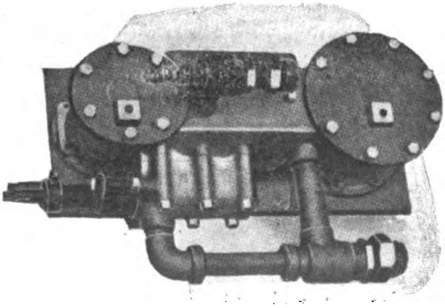


Fig. 38. Lane Engine, Showing Simpling Device.

Screw the filler cap down hard. If necessary, soften the leather washer with oil to make it air tight. Open valve *D* one-quarter turn. If the gauge shows less than ten pounds, connect the hand pump to valve *E*, Fig. 43, and pump up.

See that the engine case is supplied with oil, and open the damper in the dome over the boiler.

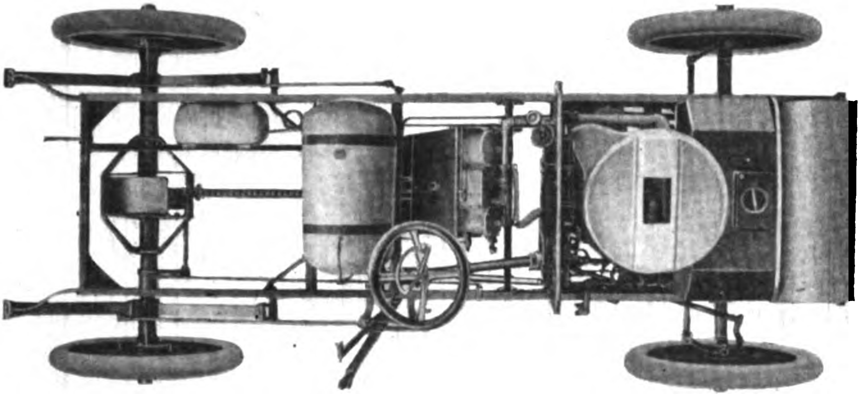


Fig. 39. Lane Chassis in Plan.

Pour about an ounce of wood or denatured alcohol into cup *G*, Fig. 42, inside the right-hand bonnet panel. This alcohol will saturate an asbestos wick under the vaporizer. Light the wick through door *H*. In cold weather burn a little alcohol in the cup under the burner nozzle. If necessary, add more alcohol to *G*. The wick should burn a minute or longer.

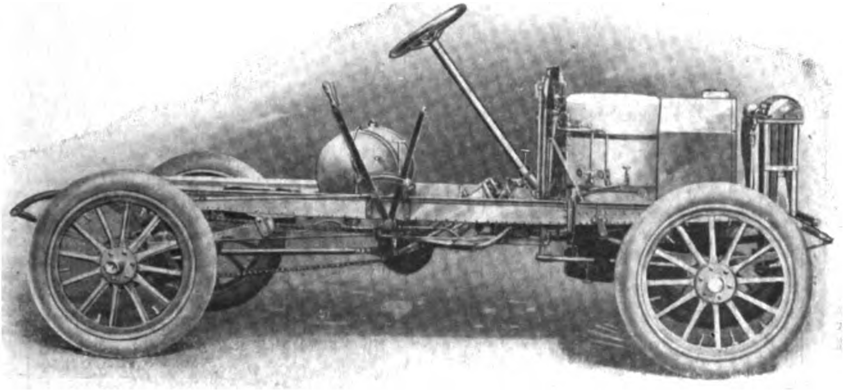


Fig. 40. Lane Chassis. Side View.

With the wick still burning open fuel valve *J* one-quarter turn and close instantly: repeat if necessary. The fire will light if the vaporizing tubes have been sufficiently heated. Open the fuel valve slowly to allow the burner to heat up. To accelerate matters, open the forced draft valve on steering column when steam pressure begins to come up.

Do not let the flame burn yellow and smoke, and do not at any time allow fluid gasoline to enter the burner. This will not happen if the vaporizer is hot.

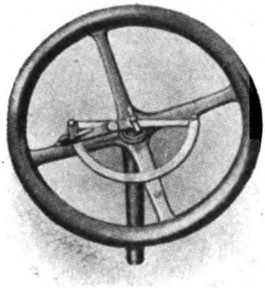


Fig. 41. Lane Steering Wheel, Throttle, and By-Pass.

Blow out the expansion tube of the water regulator by means of a valve underneath the car on the left side.

With some steam up, warm up the engine by working the car slowly back and forth. Put one foot on the brake and the other on the simpling lever, set the reverse lever either full forward or full back, and open the throttle valve momentarily several times till the car just moves. Then move reverse lever backward and forward till car moves freely. Go slow: haste may result in knocking out a cylinder head.

For maneuvering in close quarters and for quick acceleration the engine works better simple (with the simpling push rod in floor down); otherwise the engine should always be compound. It is not necessary to stop the car before simpling the engine.

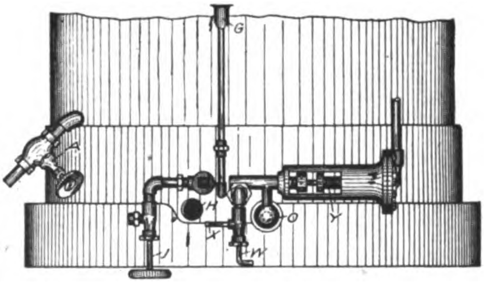


Fig. 42. Lane Boiler and Burner Fittings.

On the Road. The use of the forced draft is to turn the exhaust gases down under the car and to stimulate the fire, which processes are not necessary when the car is standing still or running slowly. When using the forced draft the damper in the dome should be nearly closed.

To shorten the cut-off bring the reverse lever back a notch or two. Always have it full ahead when starting or running slowly.

To pull out of a bad hole or up an unusual hill, use the simpling valve with the reverse lever a notch or two back.

If the valve *K*, Fig. 43, is open and the hand by-pass on the steering wheel closed, the water feed will take care of itself. (See *By-pass Valves.*)

If the fire goes out or backfires, shut the main burner valve at once, using either the emergency valve by the heelboard or the regular fuel valve *J*, Fig. 42. If the fire goes out on the road it may be due to exhaustion of fuel, low air pressure, or to the pilot light having gone out; or there may be water in the gasoline. If no liquid fuel has got into the burner the fire may be relighted without the use of alcohol if the steam is above 75 pounds.

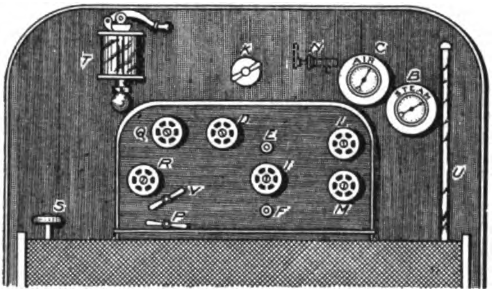


Fig. 43. Lane Dashboard Diagram.

If the gasoline has got into the burner it should be given time to evaporate before any attempt at relighting is made. If steam remains, turn on the forced draft first to help clear away the gasoline vapor, and use extreme care in relighting. If the alcohol flame is applied to the vaporizing tubes while liquid is in them, the gasoline and vapor ejected from the nozzle will furnish ample heat for speedy relighting. After the vaporizer has emptied itself in this fashion and the gasoline flame has burned out, the main burner valve may be slowly opened.

Backfiring in the burner may be due to a gas leak, perhaps at the automatic packing; or to the burner being overheated, as from insufficient draft.

If anything seems to be wrong with the burner, close the emergency valve first, and think it over afterward.

If the fusible plug blows out, first turn off the fire, then stop the escape of steam by closing valve *P*, Fig. 43. Use the auxiliary steam water pump or the hand pump to get more water in the boiler before relighting; put in a new plug also after the water is up, and open valve *P*. If valve *P* were closed the plug could not blow out if the water should get low again.

Do not let the water tank get empty. If this should happen, leave the hand by-pass valve open for the first few rods that the car runs after filling the tank, in order to allow the air to work out of the pump.

A steam siphon or inspirator is provided for filling the tank from roadside sources of supply. To use it, connect the hose to the siphon and put the strainer end entirely under the surface of the trough or stream; open the lever valve just ahead of the siphon first, and immediately open the steam valve. After the water starts, reduce the steam supply to just enough to lift the water. When the tank is full close the steam valve first. A packing ring in the hose connection is essential to maintain the necessary suction.

The air pressure is maintained automatically at a pressure determined by the clearance of the air pump on the engine. The clearance space is adjustable by a screw reached from the outside which should be screwed in to increase the pressure. In emergencies the auxiliary steam air pump may be used, or the hand air pump, or, if the pressure is excessive, the air valve *D* may be closed, which prevents the engine from pumping further.

The steam air pump may be used for inflating tires by connecting the air hose at *F*, Fig. 43; if more than tank pressure is desired, close valve *I* to prevent the air from going to the tanks.

Lubrication. The makers of the Lane car recommend mineral cylinder oil rather than the usual steam cylinder oil. In winter it may be thinned with 23° red paraffine. This oil is normally supplied only to the engine case, which is enclosed oil-tight and should be filled with oil above the partition. Enough oil is carried by the piston and valve rods into the cylinders and steam chest for ordinary interior lubrication. A stroke of the cylinder oil pump is, however, beneficial on starting or when running very slowly. To feed to the cylinders, open valve *R*, Fig. 43, and work pump *T*. By opening valve *Q*, oil is fed from pump *T* to the steam pumps instead of to the cylinders.

Refill the engine case as often as inspection shows it to be necessary, and dip into the oil to be sure that its consistency is right. If the oil is dirty or thick, change it completely. Water under the oil is drawn off from the petcocks underneath.

Packings. The stuffing-boxes of the piston and valve rods and the steam pumps should be tight enough not to leak appreciably, yet not so tight as to cause needless friction. The presence of water in the case after a run indicates leakage. To test leakage, remove the front footboard and engine case cover and run the car slowly under its own power. Occasionally the stuffing-boxes will need to be repacked.

If a gland leaks badly the packing will wear out quickly. On the other hand, there is no object in tightening the gland excessively. It is well to take a look at the glands after every hard run and tighten them a trifle, if needed.

Use *Vulcabeston* packing for piston and valve rods, also a ring of it top and bottom for the air pump gland with an ordinary soft asbestos wick between. Apply the latter wet and graphited. For the water pump use hemp cord. Put the packing under the follower, not between it and the nut.

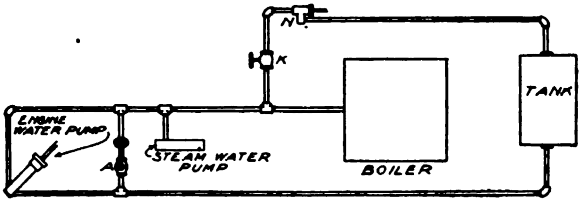


Fig. 44. Lane Water System.

By-Pass Valves. The water system is shown in Fig. 44. The hand by-pass valve *A* on the steering post is normally closed, and the automatic by-pass *N* controls the flow of water to the boiler or back to the tank. If *A* is open no water goes to the boiler, regardless of what the automatic by-pass may do. If the cut-off valve *K* (see also Fig. 43) is closed, all the water goes to the boiler irrespective of the automatic by-pass, unless valve *A* be open. In other words, the feed is automatic when valve *A* is closed and *K* is open. It is controlled by hand when *K* is closed and *A* is manipulated.

The automatic by-pass is operated by a thermostat on the dashboard, which also operates the water level indicator. This thermostat is essentially an expansion tube connected to the boiler at the desired water level. If the water is below that point the tube is filled with steam and is therefore hot. It then closes the by-pass valve and holds the indicator hand in the corresponding position. When the water level rises above the point of connection the steam condenses and the pipe fills with water, which becomes cool and allows the tube to contract, open the by-pass valve, and move the indicator hand accordingly. A second expansion tube lower down moves the indicator hand still further if the water level gets below normal. The indicator hand may move from right to left frequently, owing to the successive opening and closing of the by-pass.

When the car is cold, the indicator does not operate and the water level must be ascertained by the trycocks. To keep the expansion tubes clear always blow them out when firing up, using the blow-out valves on the left side of dash.

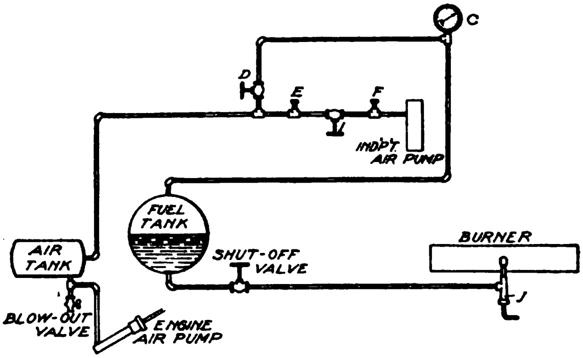


Fig. 45. Lane Air System.

The Air System. The air pressure should be 30 or 40 to 80 pounds, depending on the power desired. In case the engine air pump fails to maintain pressure automatically, investigate for leaks or clogged air valves as follows: first, the gland around the pump plunger may leak; second, the pump check valves outside the case may not seat, owing to dirt; third, oil working in around the pump plunger may have gained the valves, or it may have worked through the air pipe and clogged it at some point; and, fourth, there may be leaks elsewhere.

The remedy in each case is obvious. Gasoline absorbs some air and the pressure will go down a trifle after filling the tank even if there is no leak. To test tightness of the check valve in delivery pipe from engine air pump, loosen the union between pump and check, and hold a cup of water to close the end of the pipe. If air escapes open the check valve, clean and put a drop of heavy mineral oil on it; screw the cap down tight. The pressure may be relieved from the check valve in the delivery pipe from the steam air pump by closing valve *I*, Fig. 45. To localize a leak if there is not time to stop it, leave the air valve *D* closed. Hunt for trouble four with soapy water or oil.

Water Pump. The water pump may fail from being air bound. To clear it of air, run with by-pass open. The most probable cause is leaky packing in control valve *N* or a leak in the suction pipe. Occasionally dirt may prevent the check valve from closing.

Fuel Regulator. This regulator is of the ordinary diaphragm type. To adjust it, screw the adjusting screw *Y*, Fig. 42, inward to increase the boiler pressure. The normal pressure is about 325 pounds. Do not screw the packing gland tighter than is necessary, or the automatic will be sluggish. If water issues around screw *Y* the diaphragm is cracked and must be replaced. For packing the valve stem use asbestos wick, wet and graphited. Never put oil on this gland.

General Hints. Use the regulating valve *W*, Fig. 42, of the pilot light only to regulate the flame, not to shut it off. If the nozzle *X* becomes choked, unscrew it with pliers and open the hole with a fine wire; do not enlarge it. The pilot flame should be four to six inches long.

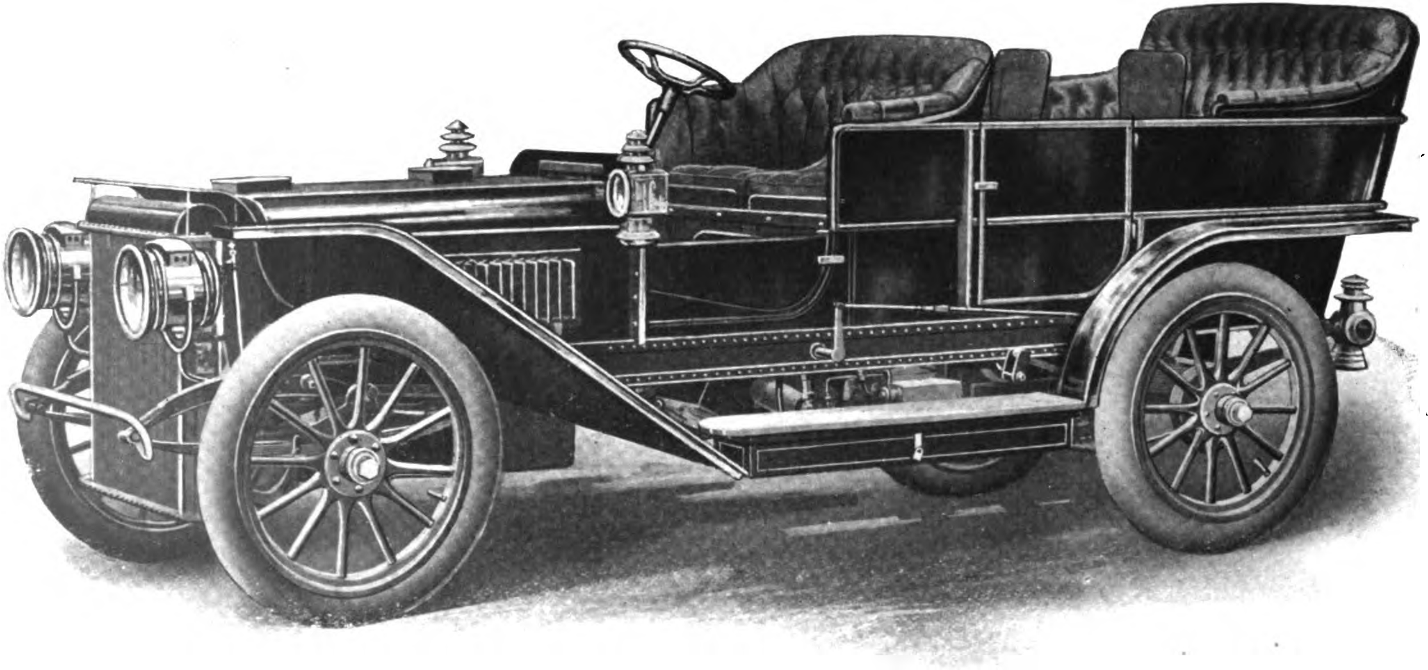
Blow off the boiler frequently by opening valve *A*, Fig. 42, if the water is hard or dirty. Close valve *P*, Fig. 43, in fusible plug fitting, if the fire is on when blowing off; don't forget to open it again.

To clean the vaporizing tubes, unscrew the plugs at the ends and take off the automatic regulator. To remove the alcohol torch, unscrew the cap from the end of the left side of the burner box outside and disconnect the union on the right side.

If any gasoline joints are taken apart, test them, after assembling, under pressure with a lighted match.

In freezing weather the garage must be kept above freezing temperature, and the car must not stand idle out doors long enough to allow the small exposed pipes to freeze. To lay up the car, clear all parts thoroughly of water.

The engine bearings are adjusted for wear as follows: main shaft bearings, wrist pin bearings, eccentrics and crosshead slides, by removal or adjustment of liners. The crosshead slides must bear on balls with some pressure to prevent their slipping. Other small parts are replaced when worn.



THE LANE STEAMER
Seven-Passenger Touring Car; 30 Horse-Power.

STEAM AUTOMOBILES

PART II

FLASH STEAM GENERATORS

In the foregoing discussions a body of water large enough to be treated as a reservoir of energy which may be drawn upon slowly or rapidly according to fluctuating road conditions has been dealt with. The type of generator which is now to be considered operates on an entirely different principle—that of generating at each individual instant approximately the precise quantity of steam demanded by the engine, be that quantity small or great.

In substance, the flash steam generator is simply a small, continuous steel tube whose area may be that of a half-inch or five-eighths inch circle, or even less, and which is bent in a coil of suitable form in order to present its entire surface to an ordinary burner. Into one end of this water is pumped, slowly or rapidly, according to the demand for steam. This water gets hotter as it passes along the tube. Steam is formed, but as the coil is horizontal, the steam cannot rise as in the fire-tube boiler. Instead, it is carried along with the water, to which the formation of steam lends accelerated velocity. At some point or other in the coil the water has passed entirely into steam; beyond that point the steam is superheated. The outlet of the coil is connected to the engine through the throttle valve, if there is one. None of the steam is stored, and there is no reserve energy save what may be due to the quantity of water in the generator tube. This quantity has no relation to the power of the engine, since the rate of steam production is determined solely by the heat of the fire and the wetted surface of the generator tubes.

Obviously an apparatus of this sort cannot be treated like an ordinary boiler. The smaller the quantity of contained water, the smaller will be the capacity for a spurt. Consequently the generator and fire must be large enough to supply the maximum demand on the worst hills. Further, it is manifest that the fire and

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water must exactly balance each other under all conditions. An excess of fire would produce dangerously high superheat in the steam, and an excess of water would immediately result in wet steam. The smaller the capacity of the tubes, the more rigidly is this true. In the (theoretical) extreme case of no capacity whatever no throttle valve would be used, and the fire would have to be regulated up or down in exact proportion to the flow of water to the generator. The fire would have to be extinguished on the briefest stop, and any chance drop in pressure would stop the car.

The chief advantage of the flash generator over the fire-tube boiler is its immunity from danger of explosion, and its almost (though not quite) equal immunity from damage if the water supply is reduced. In the flash generator there is no such large quantity of water as in the fire-tube boiler, and a continuous steel tube, unlike a riveted or welded shell, cannot rupture in such a way as to liberate at once all the water it contains. At the utmost, the tube might crack or split, allowing the water to leak away rapidly, but with nothing resembling an explosion. Again, if the steel tube should become red-hot it might be weakened, but a leak would not necessarily result.

To apply the flash generator principle in a practical manner, it is necessary to use a series of flat superposed coils, since one coil alone would be too short to provide sufficient heating surface. In order to extract as much heat as possible from the products of combustion rising from the burner, it is usual to introduce the cold water into the top coil of the series, so that the water goes down instead of up. To prevent the steam from backing up in the coils, and to prevent the heated water from ascending, the end of each coil is bent up to the top of the generator before connecting it to the next lower coil. The lowest coil or coils contain only superheated steam.

TYPES AND CONTROL SYSTEMS OF EARLY FLASH GENERATORS

The Serpollet System. The flash steam generator was first used on automobiles by the Frenchman, Leon Serpollet, and in the early Serpollet generators the flash principle was carried to an extreme in minimizing the quantity of contained water. The tubes, instead of being circular, were flattened and bent into a U-shaped section, thereby reducing their cross-section to a minimum, without loss of heating surface. The walls were exceedingly thick, and acted to some extent instead of hot water, as a reservoir of energy. The superheating coils, indeed, were customarily worked at a low red heat. Owing perhaps to the tendency of these very small cross-sections to clog when hard water was used, the U section tube was abandoned by Serpollet some years ago.

In the Serpollet system the fuel (kerosene) and water were pumped by simultaneous strokes of pumps suitably proportioned. One lever operated both pumps, and the stroke of both could be changed at will, thus giving slow or rapid production of steam. The engine, to avoid difficulties due to extreme superheat, had single-acting pistons with poppet valves similar to those used in gas engines. A throttle valve was provided, but was used only for starting and stopping, not for regulating speed. The latter was accomplished partly by varying the stroke of the pumps—the effect of which was to raise or lower the steam pressure—and partly by regulating the cut-off. With a given steam pressure the torque was increased for hills by lengthening the cut-off, and *vice versâ.* A special feature of the Serpollet system was a relief valve located between the water pump and the generator. This relief valve acted partly as a by-pass to divert water going through the pump back to the tank, but it also automatically allowed the generator to discharge its contents backward into the tank in case of excessive pressure such as might arise from a full generator and hot fire, immediately followed by complete or nearly complete cessation of the demand for steam.

From the characteristics of the Serpollet system the manner of driving is readily inferred. Since the feed of both water and fuel is proportioned for a given stroke of the pump to the speed of the engine and therefore of the car, it follows that the supply of steam is not affected by the speed of the car. In other words, an increase in speed automatically furnishes the added steam, provided that speed increase does not necessitate greater torque. On the other hand, if greater torque is required it must be accompanied by a still further steam supply, such as lengthened pump stroke furnishes. If the cut-off were lengthened without other change, the demand for steam would be increased thereby, and unless this demand were supplied by increasing the stroke of the pumps the result would presently be a drop in pressure; therefore, to maintain the benefit of a longer cut-off the pump stroke must be increased.

As the steam supply in the Serpollet car was strictly hand-to-mouth, it followed that the driver had to anticipate a change in road resistance or he found himself, on the one hand, stalled on a hill, or, on the other hand, loaded up with more steam than the engine could use. It was the regular practice with Serpollet cars to increase the pump stroke as much as possible in advance of striking a hill, thereby ensuring a hot generator and plenty of steam. Similarly the stroke was shortened before reaching the top. In this connection the greater effectiveness of a comparatively full generator as contrasted with one nearly empty is important. In the former, steam is made more rapidly in proportion to the greater wetted surface of the coils.

The proper way to stop a Serpollet car was to shorten the cut-off beforehand so as to have very little water in the generator. Consequently to get up to speed quickly, it was necessary to pump additional water by hand. This, of course, by upsetting the balance between fuel and water, tended to produce wet steam, and the hand pump was discontinued on attaining speed.

The White System to 1906. The White system, in both its early and its present forms, differs from the Serpollet system in several leading particulars. First of all, it is not a strictly hand-to-mouth system. The generator contains a sufficient supply of water to act as a reservoir for brief emergencies. By this fact the use of a conventional throttle valve is made possible, thereby giving direct control of the engine. The fuel and water feeds, instead of being rigidly linked, are separate, and are governed by mutually interdependent automatic devices.

In Fig. 46, the White system is shown diagramatically in its 1904 form, which was not greatly changed in 1905-6. For simplicity the generator *A* is drawn as a continuous coil in which the water enters at the top. In reality, the end of each coil is connected to the beginning of the next by a riser passing over the top of the generator, in order to prevent the water in the upper coils from running down. The lower coils contain only superheated steam. The burner is shown at *B*. It is supplied by air pressure on the fuel tank *J*, as is the usual American practice. *C* is the water tank, and *D* a pump run by the engine from which water passes through the hand pump *E* to the generator. From the bottom of the latter steam goes through a hand shut-off valve to the engine by way of pipe *H*.

Either the hand pump *S* or the power pump *R* is used to raise air pressure on the fuel tank *J*. From thence the fuel goes through the main valve *K* and the main burner valve *L*, operated either from the side of the car or from the driver's seat, to the thermostat *M*, which will presently be explained. Thence it passes through the vaporizer *N* to the burner nozzle *O*. *P* is the pilot light, the fuel for which is heated by the pilot flame itself, and controlled by the valve *Q*.

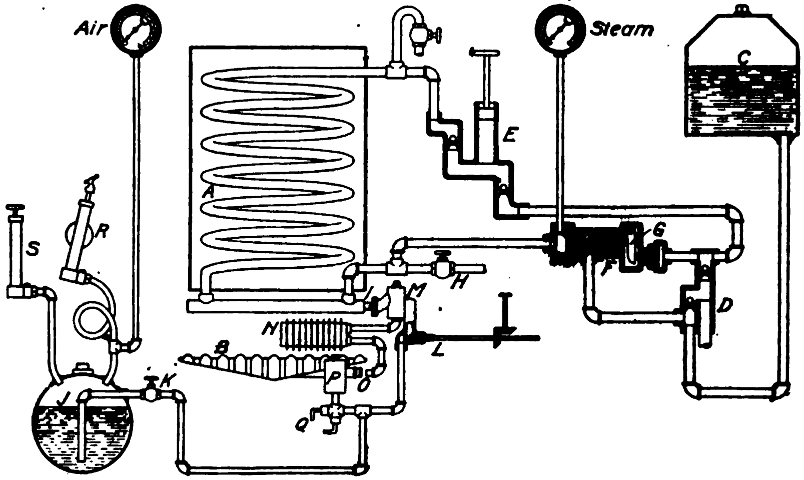
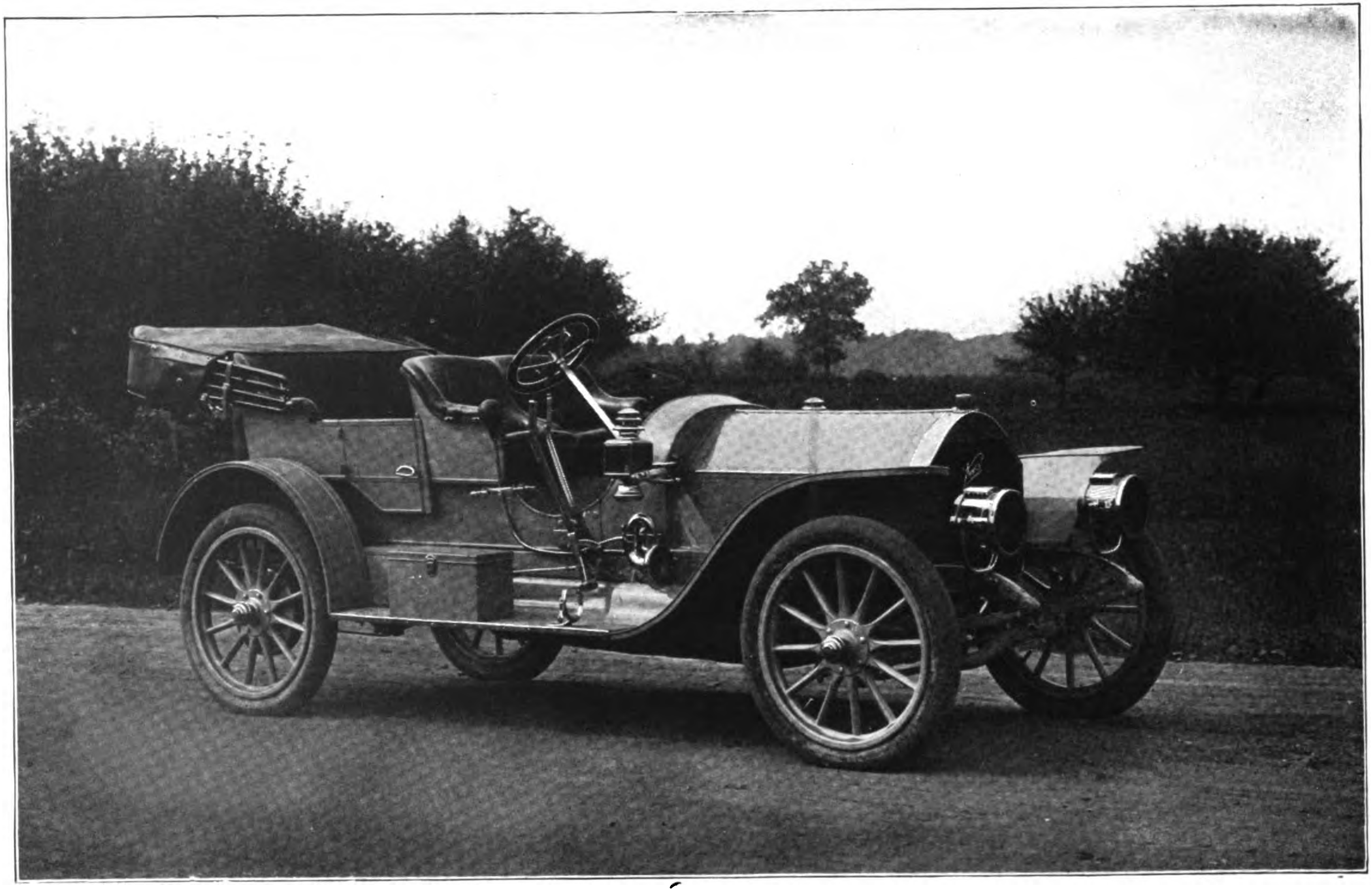


Fig. 46 White System—1905–1906.

As before intimated, the water and fuel controls are mutually interdependent. The water feed is regulated by the steam pressure; the diaphragm regulator *F* controlling the by-pass valve automatically in the same manner that the diaphragm regulator of the fire-tube boiler controls the burner valve. The left-hand end of the regulator communicates with the steam pipe and the steam gauge, and a diaphragm therein acts through the lever *G* on the by-pass valve. When the pressure rises above the by-passing point—about 350 pounds in the 1904 cars—the by-pass valve is opened and the water returns through the body of the regulator to the intake of the pump instead of going to the generator.

The burner is controlled, not by the pressure, but by the temperature of the steam. When the by-pass valve opens and water ceases to enter the generator, the supply of water in the latter diminishes by evaporation, and coils formerly filled with water presently contain steam. The superheat is, therefore, increased and the temperature of the thermostat *I* rises. This thermostat consists of a copper rod in a steel tube so arranged that expansion of the copper rod closes a fuel valve in the casing *M*. Presently, therefore, the burner is shut off by the rising temperature of the steam, although the pressure may not have materially diminished. With the fire out, however, the engine rapidly depletes the steam supply in the generator, and presently the pressure drops to such a point that the by-pass valve closes. As the pump *D* is connected to the engine and runs at a rate proportioned to the speed of the latter, water is thrown rapidly into the generator, since the pump is made larger than is necessary to take care of the maximum demand for steam. The incoming water cools the generator, and the steam temperature drops to such a point that the thermostat re-opens the valve in *M*. The fire is not reduced and augmented by degrees, but rather goes on and off smartly, being rekindled from the pilot light each time. When the car is running under light load, the fire is off most of the time. As the demand for steam increases, the fire is on for longer and longer periods, and by-passing is less frequent. When the fire is on continuously the maximum capacity of the power plant is reached.

The manner of driving White cars of the above models differs, as may be expected, from that of driving the Serpollet. There is not the same necessity for constantly watching and anticipating road conditions, since the generator capacity is sufficient to tide over the interval between the movements of the by-pass valve and the thermostat. On fairly level roads and at moderate speeds the automatics simply take care of themselves, and the driver's only care is to maintain proper pressure on the fuel tank. On the other hand, it will be noted first that the thermostat always follows the by-pass valve, but at a distance, as it were. That is, the water entering the top of the generator must travel through the generator before the thermostat is "aware" of any change. This is not absolutely true, but it roughly expresses the condition. Consequently the reserve capacity of the generator is not a complete guarantee against the necessity of anticipating road conditions. For example, if one happens to strike the bottom of a hill with the by-pass valve open and the fire off, one



KNOX CAR WITH TONNEAUETT BODY
Knox Automobile Co., Springfield, Mass.

may run quite out of steam before the thermostat feels the water supply and gets the fire started. In such a case it is not sufficient merely for the fire to open up, as some additional time is required to convert the water into steam; consequently it is the rule with White cars of the above models to make sure (usually by opening the throttle) that the fire is on before the grade is encountered. The sudden demand for steam produces the needed drop in pressure to close the by-pass and throw cold water freely into the generator. If this occurs in time to start the fire, even the worst hills are taken with ease. It is to be noted that the more slowly the engine runs, the more steam per revolution it may receive from the generator, since the fire is in no way dependent on the engine for its supply of fuel. The pump *D* delivers fully as much water per stroke as the engine can use in the form of steam, and the fire by continuously burning cannot fail to raise it to the by-passing pressure. This fact, coupled with the large reserve power of the White engine and the generator, explains the remarkable hill climbing power of these machines in spite of the small storage capacity of the generator.

In case it is not convenient to "rush" the approach in order to have ample water and fire for the ascent, one may shut off the fire by the hand valve. This cools the thermostat and also causes the steam pressure to go down; the by-pass valve opens automatically, and at the proper moment opening the hand burner valve gives a full fire and rapid steam production for the ascent.

The same rule indicated above applies when a shorter stop is made. The fire is shut off on closing the throttle or a little earlier, the pilot valve remaining lighted. Thus the thermostat is allowed to cool and a full fire is assured immediately on starting. It is true that the thermostat will close if the car is standing still, but it would probably be shut instead of open on restarting the car, and the result would be no fire till the car had run some distance. Occasionally, in the earlier White cars, the thermostat failed to operate owing to sticking or clogging of the valve, and being located directly over the fire it would "burn out" with accompanying damage to the generator coils. In the present White cars the thermostat is located away from the fire and operates in quite a different manner.

The hand water pump *E*, Fig. 46, is seldom used except in case the power pump *D* fails to operate. The 1905 and 1906 White cars have two power pumps, one of which operates through the automatic by-pass valve, and the other is intended for use on hills. The latter pump normally by-passes all the time, but its by-pass valve is closed by hand when extra water is required. In the present White cars both pumps are power-driven; they deliver into the same pipe line, and operate through the same by-pass valve.

The power air pump *R* is located at the front end of the engine, and by pressing a foot plunger it is swung into engagement with a pin projecting from the crosshead. This type of pump has been replaced in later models by one worked continuously from the engine and having its intake check valve held open when air is not desired. The hand pump *S* is used to pump up pressure for starting or after refilling the tank.

In all the White cars the exhaust passes into a condenser at the front end of the bonnet, and is pumped thence to the water tank *C*. The condenser does not maintain a vacuum, as the condenser pump is not adapted to that end. However, the condenser obviates the necessity of frequent stops to refill the tank. Generally one filling of the water tank will last as long as a filling of the fuel tank.

All the White engines, prior to 1909, have had the Stephenson link motion. At medium to high speeds the reverse lever is "hooked up," thereby shortening the cut-off to about $\frac{5}{8}$ stroke in the high-pressure cylinder. The ratio of cylinder volumes is such that with this cut-off the steam is expanded about four times. For starting and for slow speed the cut-off is lengthened to full stroke in the high-pressure cylinder, and the expansion is done in the low-pressure cylinder. The engine is provided with simpling valves by which live steam is admitted direct to the low-pressure cylinder, for starting and for overcoming momentary, unusual resistance. It is customary to use these valves only until the car gets in motion. Besides the added torque given by simpling, the engine is helped over the dead center, when otherwise it would be unable to start owing to the steam having cut off just before the end of the stroke.

WHITE FLOW MOTOR SYSTEM

From 1907 to the present time the White steam cars have employed a control system differing essentially from that previously described and known as the *flow motor system*. By this system two important advantages are gained. The thermostat, instead of acting on the fire, acts as a supplementary control on the water supply and is removed from the direct heat of the fire. This eliminates the tendency to "burn out" which was the chief weakness of the thermostat in previous models. Aside from that, in the new control system the regulation of fire and water is simultaneous. It is not necessary for the water to traverse the length of the generator piping before its effect is felt by the fire; an increased water flow is accompanied immediately by increased fire. For this reason it is practically impossible to stall a White car of the later models by a change in grade or surface, however abrupt.

In the following pages the 1909 and 1910 White cars will first be described, and then the differences between these and the 1907 and 1908 cars noted. Where not otherwise stated the illustrations are those of the 20-H. P., 1909 Model *O*.

As regards the engine, generator, burner, condenser, and the by-pass valve and its diaphragm regulator, the differences between the later and earlier White cars are matters of detail only. In approaching the chief points of difference, viz, flow motor and thermostat, the first point to be noted is that the capacity of the pumps is purposely in excess of the utmost demands of the engine. As a certain quantity of water is pumped per revolution of the engine, it follows that the by-pass valve will open more frequently as the throttle is reduced and the cut-off shortened. Again, the burner regulation by the flow motor is not absolutely "on and off" like a switch, but the fire may burn at a considerably reduced rate without being extinguished.

Fig. 47 shows in diagram the course of the water from the tank 96 through pipe 18, water pumps 22, 23 and pipe 19 to the flow motor 120, and to the thermostat 122. The thermostat is arranged as a shunt in the water line, part of the water going through it by pipes 100, 130, and the main flow going through the flow motor. The two streams combine in pipe 83; and, after passing through the feed water heater 5, the stream goes by pipe 127, 128 to the generator. 25 is the water regulator. When the pressure exceeds 550 pounds the by-pass valve opens and the water goes by pipe 34 back to the tank. 37 and 214 are steam connections. 121 is a return pipe connecting with a relief valve in the flow motor, through which the excess returns to

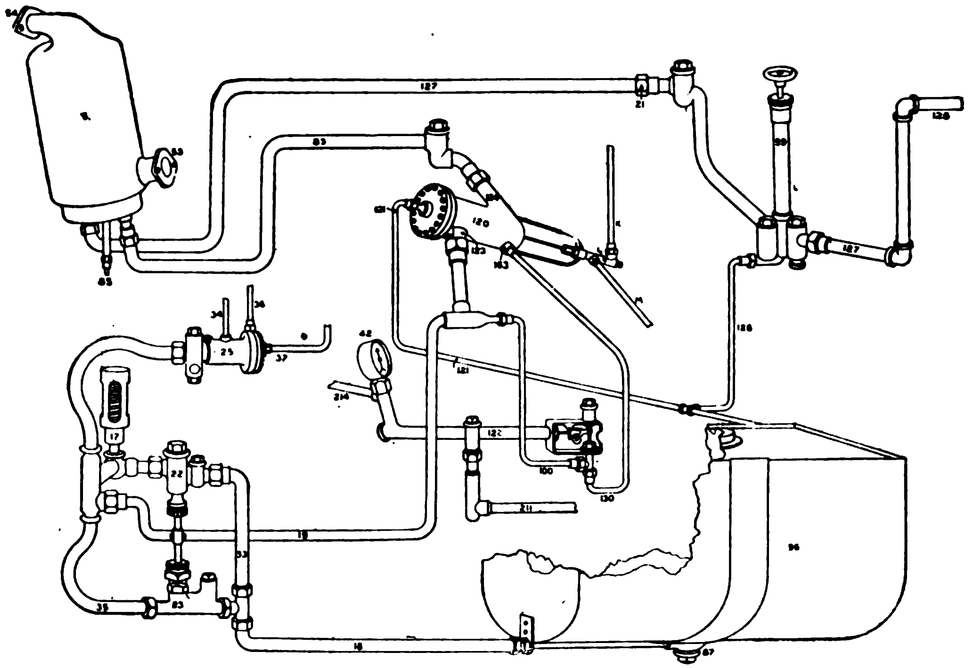


Fig. 47. Water Connections, White—1909–1910.

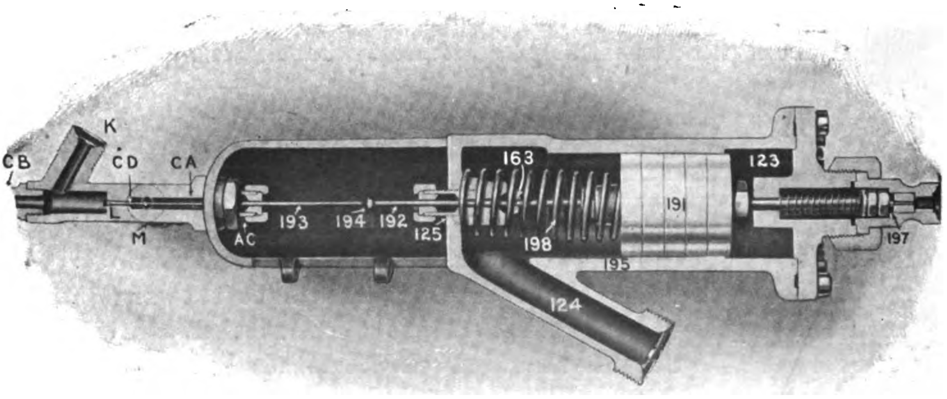


Fig. 48. Flow Motor, White—1909–1910.

the tank when the flow motor receives more water than it can handle.

Fig. 48 shows the flow motor in section. Water enters the cylinder at 123 through a connection not shown. It flows past the piston 191 through a graduated groove 195, and out through 124. As the flow increases the piston is pushed forward, compressing spring 198, and the more it is pushed forward the more water goes through the groove 195. Near the end of its travel the relief valve 197 is pulled from its seat and the excess water goes to the tank. Attached to the piston and passing through stuffing boxes 125 and *A C* is the adjustable stem 193 which terminates in the fuel valve *L*. Liquid fuel enters from the tank at *K* and passes out at *M* to the burner. The valve has a long taper and is fully opened when the piston has moved about ¾ of an inch. The adjustment 194 in the valve stem is set so that when no water is flowing the valve *L* is positively seated by the tension of spring 198.

Two views of the thermostat are shown in Fig. 49. Steam enters from the generator at 216 and passes out at 217 on its way to the engine. Water enters at 200 and goes out at 204. When the steam temperature exceeds 390° C.—which is the normal running temperature—the rod 207 expands and pushes up the bell crank lever 205, thereby opening the needle valve 201, allowing water to pass to the generator. When the temperature drops a little below 390 degrees, valve 201 closes and the generator receives only the water passing through the flow motor. Attached to the thermostat is a small *pyrometer* or temperature indicator which shows when the thermostat is working correctly.

The action of the flow motor and the thermostat may now be understood. The forms of groove 195 and the fuel valve in the flow motor are such that, while the ratio between water flow and fuel flow is constant, the fuel supply is slightly in excess, *i. e.*, the steam tends to get hotter and hotter; consequently when the car runs the steam temperature will presently exceed the normal, with the result that the thermostat valve, which at first was closed, now opens, allowing water to enter the generator in addition to that going through the flow motor. This additional water does not affect the fire in any way, but it cools the generator, so that presently the thermostat valve closes. In other words, while the flow motor controls the fire in sub-

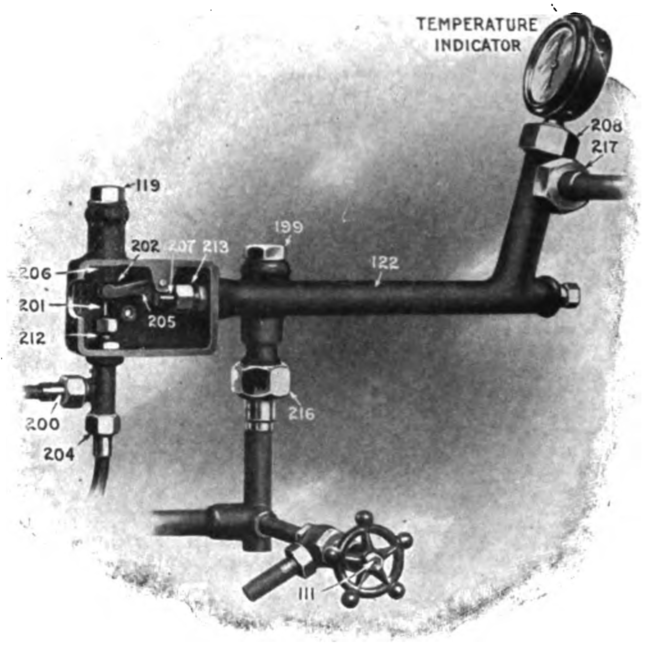


Fig. 49*a*. Thermostat, White—1909–1910.

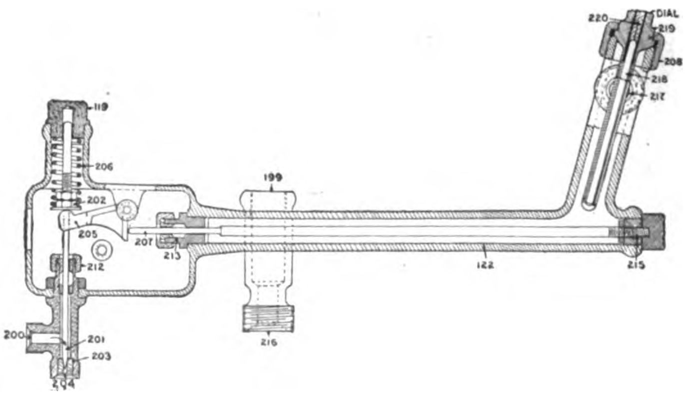


Fig. 49*b*. Cross-Section of Thermostat.

stantial proportion to the demands of the engine, the thermostat valve, by opening and closing, preserves the exact balance between the fuel and water. This is the action when the by-pass valve is closed.

When the by-pass valve opens, all flow of water to the generator ceases and the flow motor piston, returning to its idle position, extinguishes the fire. This shutting off and relighting may take place in rapid recurrence—once or even several times a minute.

The foregoing describes the operation when the pumps are throwing water fast enough to force the flow motor piston to the end of its travel. When, however, the pumps run slowly, the action is slightly different, though the result is the same. The thermostat valve will still open and close, because the fuel supply is still in excess of the water passing through the flow motor, but when the thermostat valve opens it will shunt enough water away from the flow motor to allow the piston of the latter to go back somewhat, thereby reducing the fire without increasing the total flow of water. In a word, the effect at high speeds is to preserve the temperature equilibrium by admitting more water, but at low speeds the same result is accomplished by reducing the fire.

The relief valve 197, Fig. 48, comes into play when the car is running at high speed. It will be remembered that the water pumps are large enough to throw all the water the generator can handle even at slow speed, thereby furnishing ample steam for bad hills. At high speed on good roads, therefore, they throw a great excess, which is taken care of by the relief valve.

GENERATOR AND BURNER

These parts have not been changed save in dimension and detail from the 1904 White models. The generator consists of several flat coils in series, and having, in the 20-H. P. size, a capacity of about five quarts. Water enters by the pipe 128, Fig. 50, and the steam issues from pipe 129. The end of each coil is connected over the top of the generator to the beginning of the next.

The burner *Q* has a cast-iron top plate whose concentric corrugations contain a great number of cross slits through which the mingled vapor and air issues. Fuel comes from the tank by pipe *A* through the strainer *B*, pipe *H*, main burner valve *J*, and pipe

K to the flow motor valve contained in *L;* thence it goes through pipe *M*, vaporizer *N*, and pipe *NA* to the burner nozzle *O*, which in the 1909 to 1910 cars has three orifices. *R* is the mixing tube, and *S* a shutter for regulating the air supply. The 1910 White cars use kerosene regularly, and gasoline only for firing up. Gasoline can, however, be used exclusively if desired. A smaller air supply is needed for gasoline than for kerosene. *P* is the pilot light, which is supplied by the pipe *MA*. *G* is a special "warming up" valve which admits fuel directly to the vaporizer without going through the flow motor. It gives a fierce fire and rapid steam generation when firing up, and it requires to be opened for two or three minutes only, after the vaporizer has become heated. In the 1910 car the pilot light *B* and the warming-up valve *G* are supplied from the gasoline tank by pipe *A*. Pipe *H* is separate and leads from the main (kerosene) tank through the main burner valve *J* and thermostat valve *L* through pipe *M* to the vaporizer *N* and the main burner.

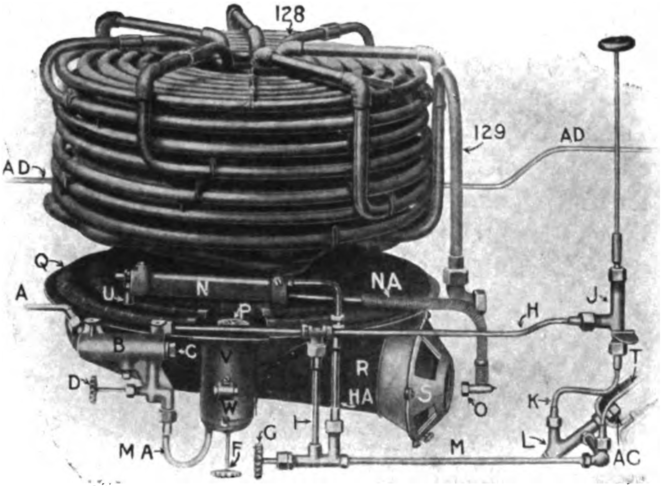


Fig. 50. Generator, Burner, and Fuel Connections, 1909 Car.

FUEL CONNECTIONS

The fuel tank is divided into two compartments *X* and *X2*, Fig. 51 and Fig. 52, of which the latter contains gasoline for firing up. In cars prior to 1909 there is only one compartment. Air is delivered to

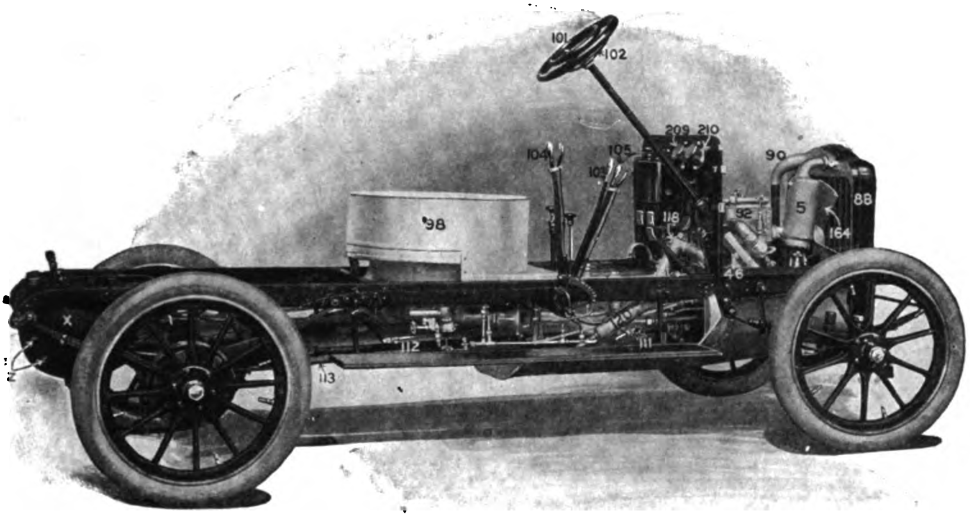


Fig. 51. Chassis—Side View, White—1909-1910.

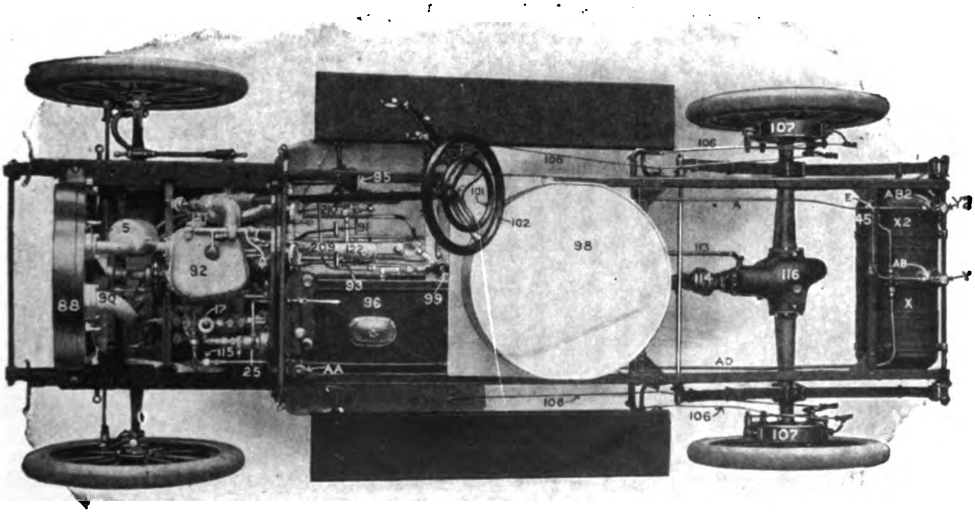


Fig. 52. Chassis—Top View, White—1909-1910.

both compartments through pipe *AD*. By means of valves *AB* and *AB2* the air pressure may be retained on either compartment and the engine kept running to raise pressure after refilling. All fire is, of course, extinguished when the tanks are to be refilled.

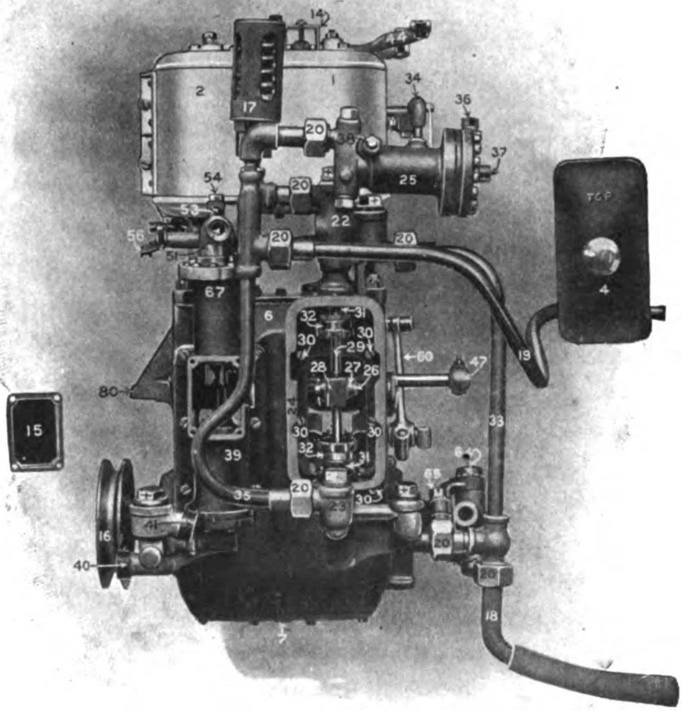


Fig. 53. Engine—Pump-Side View, White—1909–1910.

PUMPS

There are two *water pumps* 22 and 23, Fig. 47 and Fig. 53, which are mounted on the engine and are driven by a rocking lever operated either from one of the connecting rods or from a separate eccentric. They are piped in multiple and deliver alternate strokes through the water regulator 25 operating the by-pass valve. Water enters by pipe 18 and passes through check valves and pipe 33 to the lower and upper pumps respectively. Pipes 35 and 19 deliver the discharge to the generator. 34 is the by-pass return pipe.

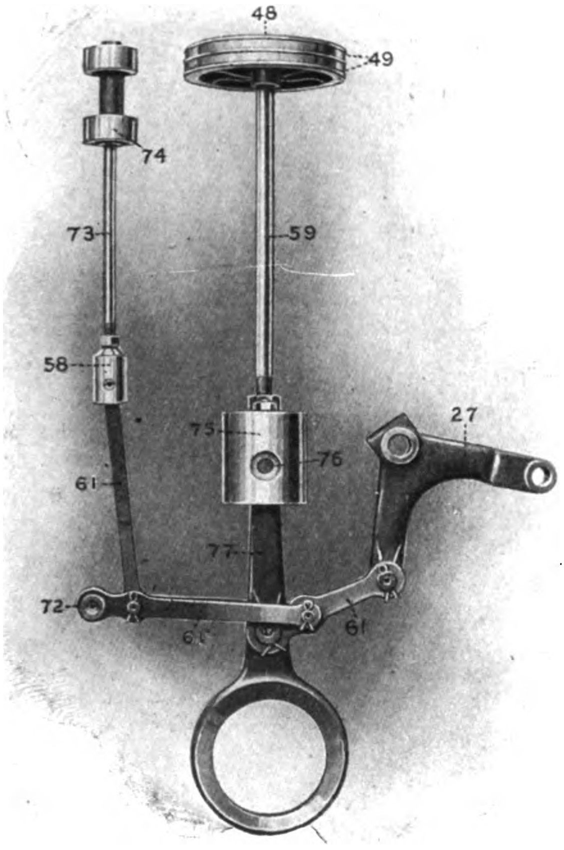


Fig. 54. Valve and Pump Gearing.

In Fig. 53 is shown the *condenser pump* 39 which returns the water of condensation to the tank. 67 is the *power air pump*. Pumps 39 and 67 are driven from a single rocker like the water pumps.

The engine is of the compound marine type with piston valves —1909 to 1910 models—and modified Joy valve gearing. This gearing differs considerably from the Stephenson link motion used in the models prior to 1909. It is, however, very simple. In consists in substance of a mechanism which causes the valve to move in step with the lateral movement of the crank pins, whereas the pistons follow the up and down motion. How this is accomplished may be understood from Fig. 54, in which a piston 48, crosshead 75, connect-

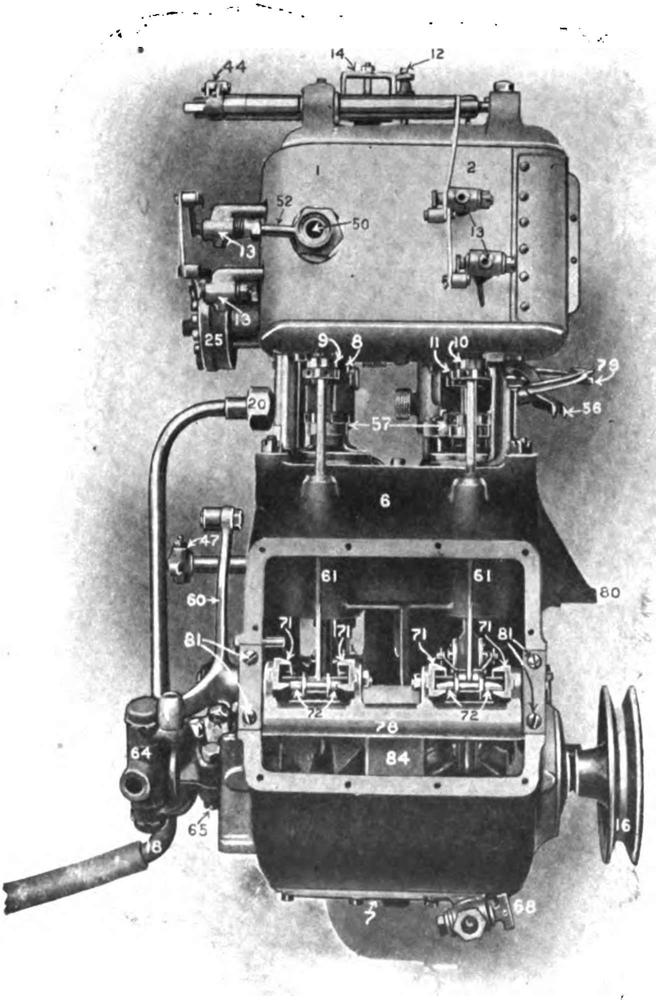


Fig. 55. Engine—Valve-Side View, White—1909–1910.

ing rod 77, and piston valve 74 are shown. The steel rollers 72 run in a grooved guide indicated by 71 in Fig. 55. This guide is pivoted and inclined at an angle, so that the rollers move up and down at the same time that they move from right to left. By rocking the guide, its slope and, therefore, the movement of the valve may be reversed, thereby reversing the engine. The cut-off is shortened in the same way. The Joy valve gear has an important advantage over the Stephenson link motion in the fact that shortening the cut-

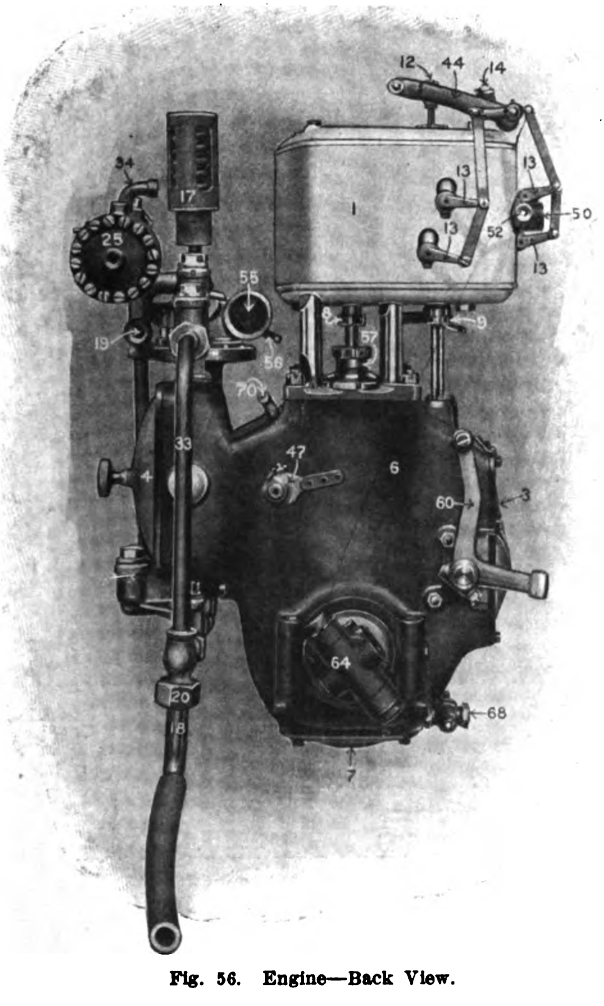


Fig. 56. Engine—Back View.

off does not, as in the Stephenson gear, increase the lead. It is, therefore, possible to drive with a moderately short cut-off at slow speeds, which is impossible with the Stephenson link motion, since with the latter the inertia of the rapidly moving parts is depended on to carry them without shock over the dead center against the early admission of steam.

The engine has *simpling valves* operated by the mechanism 44, 14, etc., shown in Fig. 55 and Fig. 56. The *relief cocks*, 13, 13, are for the escape of condensed steam when starting.

EMERGENCY LEVER

The rear axle contains a 2½ to 1 reduction gear for use on exceptionally bad grades. It is operated by a shift lever at the driver's right, and is used only when the engine is otherwise unable to propel the car. To engage this gear the car must be brought nearly to a standstill. By setting the gears in their neutral position the engine is enabled to run free. This permits air pressure to be raised before starting on the run.

MANAGEMENT AND OPERATION OF 1909 AND 1910 WHITE CARS

The 1909 and 1910 White cars differ in no essential respects except that the 1910 cars use kerosene for fuel, and use gasoline only in the pilot light and for starting. The 1909 cars, like those of 1910, have separate tanks for the two fuels, but both tanks lead into a single fuel pipe, and the user has his option of filling the main tank with gasoline or kerosene. The following description is of the 1909 cars, but with the differences between these and the 1910 noted in each case. The illustrations show the 1909 20-H. P. car, Model *O*. The larger car, Model *M*, differs from the Model *O* in no essential respect save dimensions.

Fuel Connections. The plan view of the chassis, Fig. 52, shows the 1909 tank arrangement in which both compartments *X*, *X*2 deliver through valves *AB*, *AB*2, to a single fuel pipe *A*. The 1910 model differs from this in having separate fuel pipes, the one from *X*2 leading to the pilot light *B* and warming up valve *G*, Fig. 50, and the one from *X* to the main burner by way of pipe *H* and hand valve *J*, Fig. 50. Referring to Fig. 52, the air supply pipe *AD* is in permanent communication with tank *X*. 45 is an air retaining valve where *AD* enters *X*2. This valve is usually open, but is closed to retain pressure on *X*2 when *X* is being filled. If *X*2 becomes empty, 45 is closed to prevent air from entering the fuel pipe.

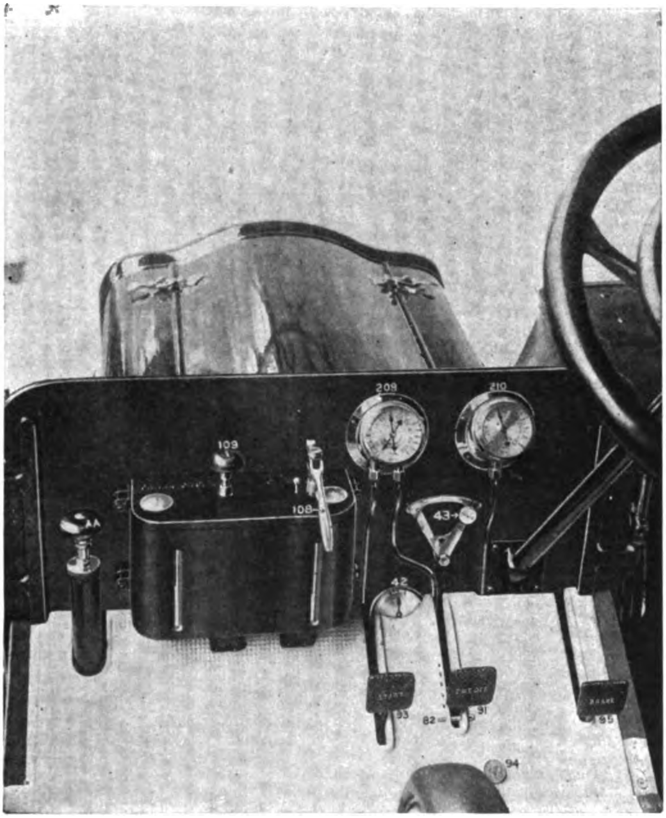


Fig. 57. Dash—Top View.

To Fill Fuel Tank. First extinguish all fire about the car, including pilot light. Close main valves *AB*, *AB*2, and all tank-, drain-, and try-cocks, also valve 45. Loosen filler cap *Y* and allow air to escape before removing. Fill through *Y* without removing strainer and screw cap down air tight. Open valves 45 and *AB*2 and run engine on tank *X*2 while pumping air pressure in *X* to fifty pounds, then close *AB*2 and open main valve *AB*.

If the pressure is exhausted from both tanks and there is no steam to run the engine, press the plunger of hand air pump *AA*, Fig. 52 and Fig. 57, down hard and turn to the left, and work the air pump till thirty pounds pressure has been raised. When pumping, close the hole in the top of the plunger with the ball of the hand. When through pumping, press the plunger clear down and turn to the right to close the valve.

Valves *AB* and *AB*2 contain ball check valves so arranged as to close automatically in case of a rapid rush of fuel, such as might result from breaking of the fuel pipe. To unseat these check valves in case they close, screw the valve stems down till shut, then open as usual.

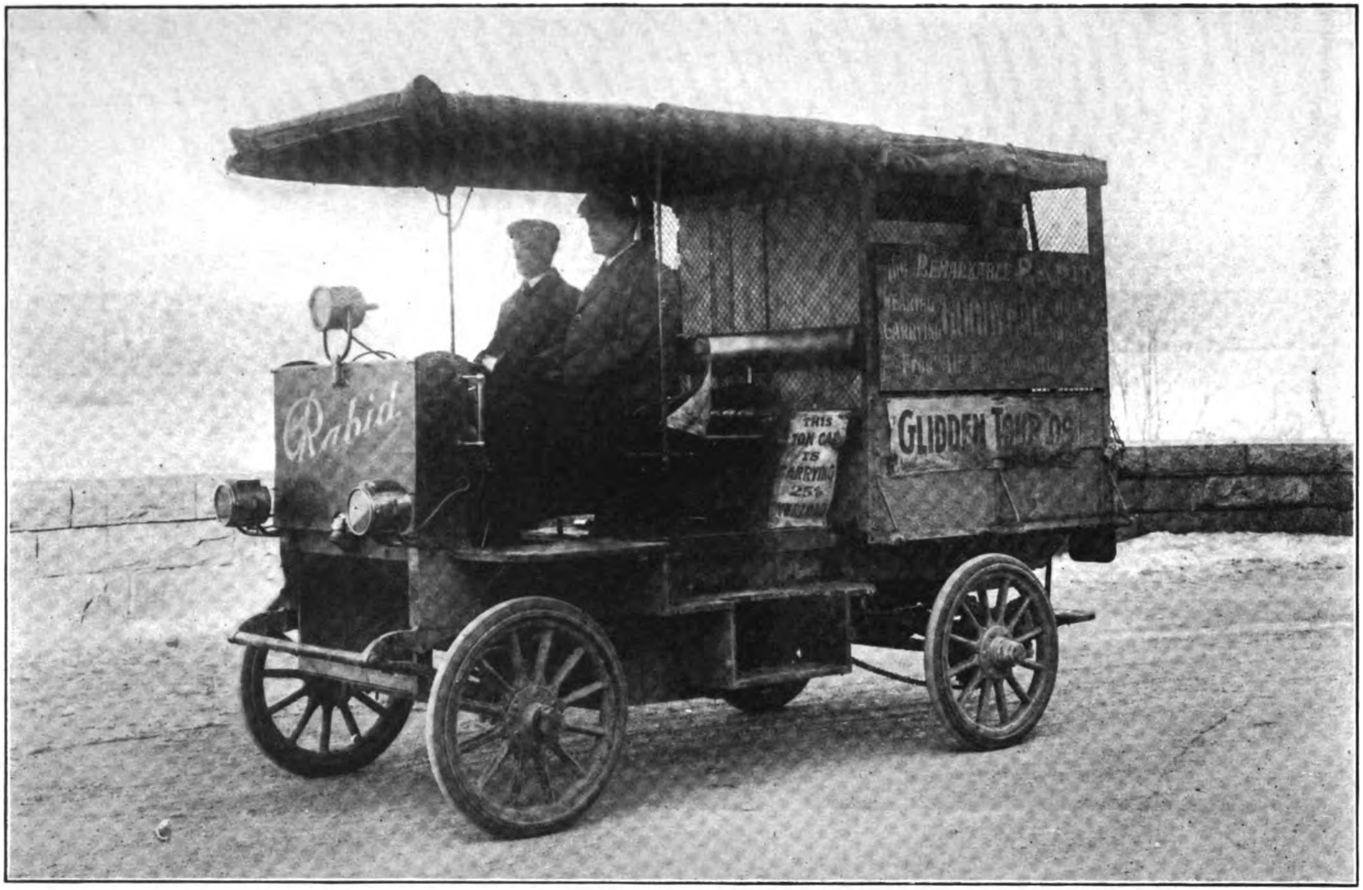
Filling Water Tank and Generator. Fill tank 96, Fig. 52, with clean water. By overflowing the tank the oil floating on the water will be flushed out. This oil comes from the engine and is carried through the condenser to the tank. It is best to flush the tank after a run, as the oil and water are then warm. Every few days remove the flush plug at the rear end of the tank, insert the hose in the forward part of the tank and flush the tank thoroughly.

To fill the generator, first press plunger of hand water pump 99, Fig. 47, down hard and turn to the left once or twice to open the valve. See that the throttle is closed and open the valve 111, Fig. 51 and Fig. 58. Work plunger till water escapes from the valve 111, indicating that there is sufficient water in the generator. Close 111 and lock pump by pressing plunger down hard and turning to the right.

If water gets into the pump when the valve is closed, the plunger cannot be forced down to open the valve. Unscrew the stuffing-box to let the water out at the top. Press plunger down and replace packing and stuffing-box.

Pilot Light. See that the fuel tank is filled, and that the air pressure is at thirty pounds or more.

To light pilot light see that valves *D* and *F*, Fig. 50, are shut. Open valve *AB*, Fig. 52 (valve *AB*2 instead, if tank *X* contains kerosene), and open valve *F* one turn or more. Open door *W* and put a lighted match inside. Open supply valve *D* slightly to admit gasoline and close at once. Open and close again till sufficient gasoline runs into the drip cup to ignite from the match. Admit gasoline as needed



THE RAPID TRUCK CARRYING A TWENTY-FIVE-PER-CENT OVERLOAD THROUGH THE GLIDDEN TOUR

The Rapid Motor Vehicle Co., Pontiac, Mich.

from valve *D* to warm pilot light thoroughly. When the pilot light is hot, fuel will cease to run into the drip cup, as it has now become a gas and will pass up through the pilot light grate and burn in the fire box. Now set valve *D* at least one turn open. The flame should burn blue and heat the pilot light grate red hot. Adjust the flame by valve *F*, see that it burns steadily without roaring, and close door *W*.

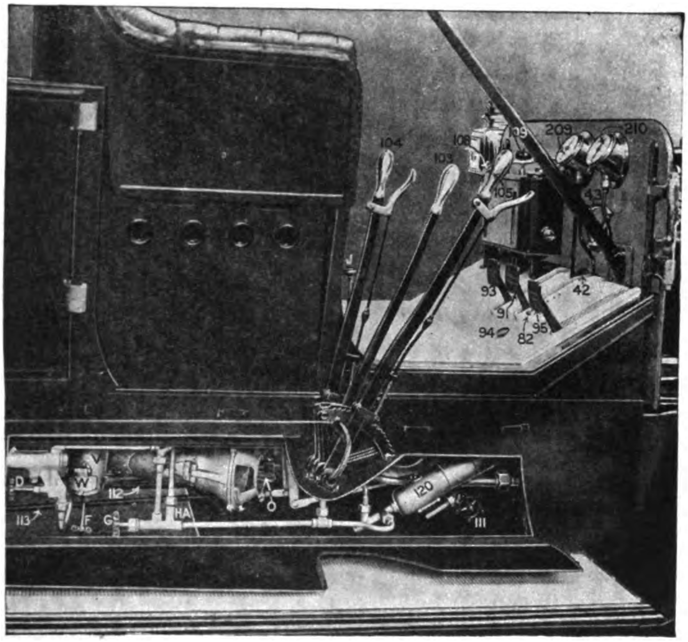


Fig. 58. Dash—Side View.

To shut off pilot light close valve *D* and open *F* wide.

To remove pilot light for cleaning, unscrew union in pipe, *MA*, Fig. 50, then give the inside of pilot light a turn with the hand to release the bayonet joint, and the whole inside comes out. A new pilot light can be inserted in this way if desired.

To Start Car. Fill the fuel tank and raise the air pressure to thirty pounds as before.

Fill water tank and pump generator full.

Light the pilot light.

Let the pilot light burn about five minutes to heat vaporizer *N*, Fig. 50. Open warming up valve *G* slightly. If raw fuel drips from vaporizer nozzle *O*, close *G* till vaporizer gets hotter. Open valve *G* four or five times, about two seconds each time, to avoid sudden rush of fuel. When main fire starts, leave valve *G* open a quarter turn and watch steam gauge closely, as the pressure runs up very fast when it starts. At 300 pounds pressure open the blow-off valve 111, Fig. 58, till steam issues. When pressure again reaches 300 pounds, adjust warming up valve *G* so that not over twenty pounds pressure shows on the vaporizer pressure gauge 209. This gauge does not show air pressure, but simply the fuel pressure in the vaporizer, and is intended to indicate the strength of the fire. Set gear lever 103 in central (neutral) position, open cylinder relief cocks by turning lever 43, Fig. 57, on dashboard to the left, push starting pedal 93 all the way forward, open the throttle slightly, and carefully work the water out of the engine by working reverse lever forward and back till the engine starts running.

Now close valve *G* and open the main burner valve *J*, Fig. 50. Open the throttle just enough to keep the engine running till the water is out, when it should run smoothly. Turn cylinder relief cock lever 43 to the right-hand position shown in Fig. 57. Now release starting pedal and push cut-off pedal 91 clear forward for about half a minute and continue running the engine two or three minutes to get it warmed up. Raise the air pressure to about fifty pounds, using power pump. The car is now ready to start.

When firing up, the warming up valve *G* should not be kept open more than two minutes or it will heat the generator red hot. If there is no steam in two minutes it is a sign that there is no water in the generator, in which case close valve *G* and pump water by hand.

The engine must be run slowly when working the water out of it and when warming up. It must not at any time be "raced" when idle. Idle running of the engine should be done in forward motion, so the fan will draw air through the condenser.

To start the car, throw in forward or reverse gear, push the starting pedal clear forward, and open the throttle slowly. Release starting pedal as soon as the car gets in motion.

Burner valve *J* is kept open while the car runs. Close it when the car stands idle even if the pilot light is left burning.

On starting after a stop do not open the warming up valve if there is steam enough to run the engine idle. Open valve *J*, start the engine idle, and run it till the water is worked out before starting the car. This will give the steam pressure a chance to come up. If necessary to use the warming-up valve, do not leave it open more than two minutes.

The proper flame for the main fire is a medium between the very blue light flame that lifts off the burner, and the heavy reddish or yellowish flame. A bad mixture may cause the burner to light back to the nozzle and is sometimes accompanied by howling. In case of poor vaporization, first see that the pilot light is burning with a good blue flame, as the pilot flame heats the vaporizer. If the fuel supply is still insufficient, change the vaporizer or clean it out as instructed.

As regards the fuel to be used, the 1909 cars should use gasoline from valve *AB*2 for starting the pilot light. If kerosene is used in the main tank, *AB*2 is closed when the pilot light has been started, and *AB* is opened for warming up and running.

With the 1910 cars gasoline is used for the pilot light and for warming, and valve *AB*2 is not closed till the end of the trip. For running up, kerosene is supplied through valves *AB* and *J*.

Cut-Off Pedal. The use of the cut-off for economy has been previously explained. The engine takes steam full stroke when the cut-off pedal 91 is pushed clear forward, and with shortened cut-off when the pedal is released. A stop pin 82 is provided to fix the shortest cut-off which the engine can use to advantage. This is determined by trial. The cut-off should never be so short as to cause the engine to vibrate.

The Engine. In Fig. 56, the simpling valves 12 and 14 are shown in position for compound running. Steam passes from the high-pressure to the low-pressure steam chest through valve 12. When the engine is "simpled" by pushing the starting pedal 93, valve 14 is open to allow high-pressure steam to get to the low-pressure cylinder, and at the same time valve 12 moves to allow exhaust steam from the high-pressure cylinder to go directly into the exhaust pipe. The passage from the high-pressure exhaust to the low-pressure steam chest is closed at the same time.

If the engine should thump when compound, but run smoothly when simple, the valve 14 is probably not seating properly and should be inspected and ground if need be.

The roller at the end of cut-off lever 60, Fig. 56, should follow the shoe connected to cut-off pedal 91. The spring attached to lever 60 should be in tension.

Water Pumps. The connection between the discharge pipe of pumps 22 and 23, Fig. 62, and the water regulator 25, contains a small strainer which should be cleaned occasionally by disconnecting the pipe 35 from the regulator. The function of the spring plunger 17 is to cushion the strokes of the pumps.

The ball check valves of the water pump should lift $\frac{1}{32}$ inch. To reseat these valves, remove the bronze balls, insert a steel ball of the same size, and tap once or twice to reshape the seat.

Condenser Pumps and Air Pumps. The condenser pump 39, Fig. 53, has mushroom check valves, which should be kept reasonably tight.

The air pump, like the condenser pump, runs all the time, but the suction check valve is normally held open by lever 56, Fig. 56. When air pressure is required, press pedal 94, Fig. 57, which operates lever 56 to release the suction check as long as 94 is down.

The needle and outlet air valves are removed for cleaning by slackening bolt 54. The needle valve is protected from dust by the wire screen 55, Fig. 56.

Throttle Valve. The throttle valve is shown in Fig. 59 closed but not seated steam tight. By withdrawing the portion 180 from the bushing 173 the valve is opened. By turning the stem so that the shoulder 181 seats against 173 the valve is closed steam tight. With this construction the seat is not scoured by the steam and, therefore, never leaks when closed. The stem has a steep-pitch screw whereby it is advanced or withdrawn in the nut or sleeve 176. This sleeve carries the frame 163 rigidly secured thereon, and the frame, by its position, limits the wide-open position of the lever 177.

To adjust the throttle, the frame 163 and sleeve 176 (considered as one piece) are turned by slackening 175 to such position that 177 does not quite touch the frame when the throttle is closed. This permits the maximum opening to be secured.

To grind the throttle, loosen the screw clamp on 163, and turn 163 to the right on 176 about a quarter of a turn. Tighten clamp 163, loosen 175, and move 177 to the right. This pushes the valve stem farther through 176, and the valve seats before the flange on

176 comes against its seat. Now turn 174 and 176 together, which will rotate the valve against its seat. By undoing 175 the stem can be slipped down and pumice put on the valve seat to grind it. When through grinding, clean the valve and slacken the stem back so that 176 will seat properly when 175 is tightened up.

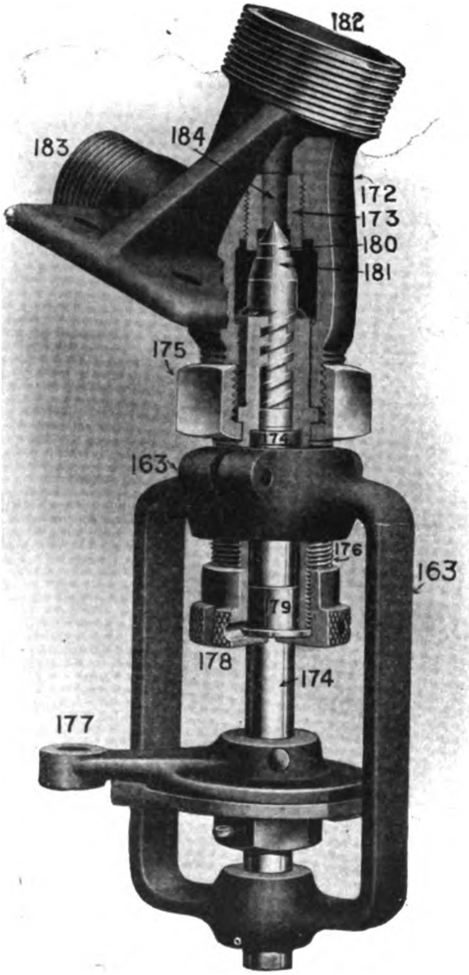


Fig. 59. Throttle.

To Clean Pilot Light. If the flame is weak with valve *F* two turns open, work valve *F* back and forth to loosen possible dirt. If this is not sufficient the pilot light must be cleaned. To remove it, close valve *D* and see that the pilot flame is out. Unscrew union on pipe *MA*, turn pilot light to the left and pull down; take apart, noting identification marks on parts. Clean with small drill furnished with tool-kit. After reassembling, blow out the dust through the stuffing-box at *F*, then replace the valve stem. In replacing cone *P* see that the slotted part is underneath.

To Clean Vaporizer. The nozzle *O*, Fig. 50, is cleaned by unscrewing and poking out the dust on deposited carbon. Occasionally run a drill through the orifices, using exactly the same size drill as is marked on the nozzle. Do not ream the hole. If fire is still poor, the vaporizer must be cleaned. Remove vaporizer door. Remove the lower part by unscrewing the nut on pipe *HA* and take out the vaporizer. Note position of end support and pipes for correct replacement. Take out plug screws in the vaporizer and clean thoroughly with large drill in tool-kit.

In replacing the screws and support see that copper gaskets are under each. See that the end support pin enters support post *U*. At the same time clean fuel strainer *B* and drain the water from the water trap by unscrewing the plug in the bottom of casting *B*.

Care of Flow Motor. If the flow motor is disturbed, *e. g.*, to regrind or replace the fuel valve 193, Fig. 48, care must be taken not to disturb the adjustment. The fuel valve for the 20-H. P. car differs from that for the 40-H. P. car, so the two must not be mixed.

The fuel valve is correctly adjusted when the valve is seated at *L* $\frac{3}{32}$ inch before piston 191 reaches its end stop. This ensures the spring tension holding the fuel valve positively shut when water is not flowing through. To adjust this when the piston is against its stop, first screw the stem 193 into 192 till the fuel valve is against its seat. From this point screw it $\frac{3}{32}$ inch more, or about five turns, and clamp with nut 194.

The relief valve 197 is easily cleaned by slackening the adjacent union.

If leakage is noted at 125, tighten the stuffing-box or repack. Do not tighten hard or it will retard the movement of the piston.

Care of Thermostat and Pyrometer. Of the two thermostat stuffing-boxes, Fig. 49, 212 is packed with water packing, and 213 with asbestos packing. They should not be screwed tighter than is necessary to prevent leakage when well packed.

To adjust the thermostat remove cap 119, and pull out stem 201. Adjust the nuts 202 *up* to raise the temperature, and *down* to reduce the temperature. The temperature should average 390 degrees centigrade; one complete turn of nuts 202 will change the temperature about sixty degrees. If the pyrometer or temperature indicator is known to be fairly accurate a thermometer is not necessary, but the car must be run long enough to get a constant temperature. The temperature cannot be accurately set when the car is standing.

The principle of the pyrometer is similar to that of the thermostat. 219 is the expanding element, and 218 a non-expanding stem which communicates the movement of the lower end of 219 to the indicator above. Occasionally the pyrometer should be checked by putting a thermometer into the hole 199 and running the car till the temperature becomes constant. If correction is required, it is made on the dial.

Water Regulator. In Fig. 60, 37 is the steam connection, and 36 the gauge connection. The by-pass valve 141 is opened by lever 140 when the steam pressure is sufficient to compress the spring. Water then goes through the regulator and out at 34 instead of going to the generator.

To adjust the by-passing pressure, turn the worm 38 to the left to increase the pressure, and to the right to decrease it. The water should by-pass at 550 pounds steam pressure.

To remove the diaphragm, take out the regulator by blowing off the steam pressure and disconnecting at 34, 36, 37, and 145. Be careful not to lose valve 141. Turn worm 38 to the right till spring tension is entirely relieved, before removing screws from cover. Count the turns given to worm 38. Mark the cover 133 and plate 97 for correct replacement, also see that 97 is replaced with its concave side next to diaphragm.

When reassembling, tighten the cover screws evenly, a little at a time, several times around. Turn 38 to the left about two-thirds the number of turns given it on disassembling. Put valve 141 in position and reconnect the regulator except at 34. Open blow-off valve 111 and oil valve 118, Fig. 51, and pump oil around the dia-

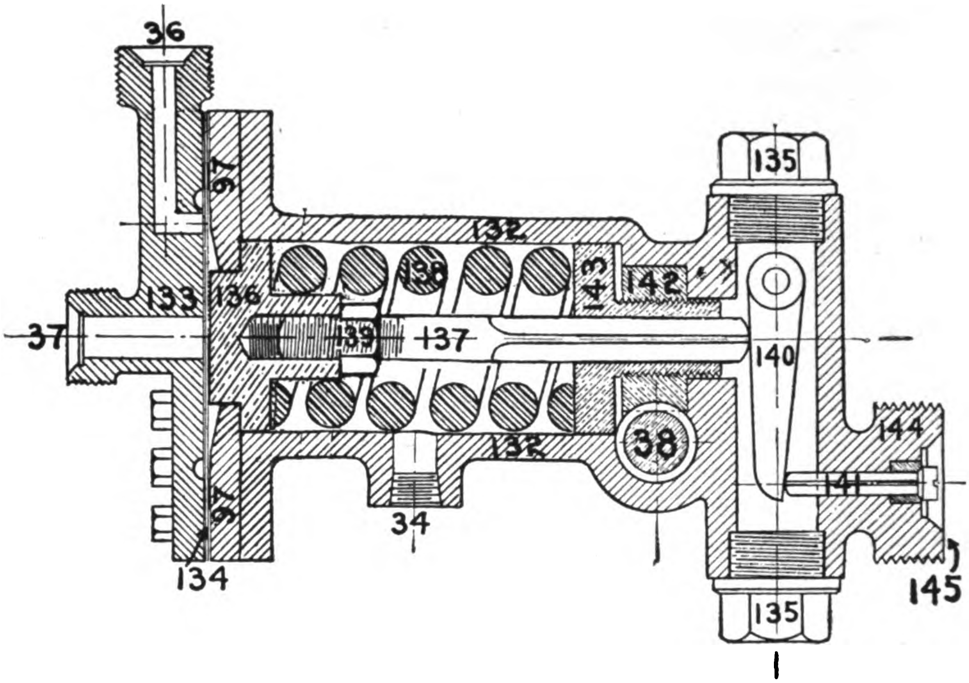


Fig. 60. Water Regulator.

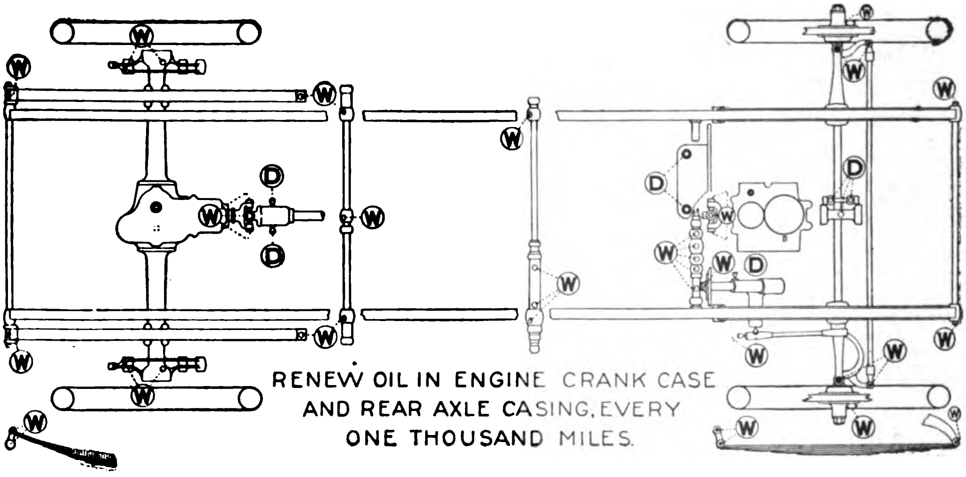


Fig. 61. Lubrication System.

phragm from the cylinder under oiler 108, Fig. 57, till the oil runs from 111. Close valves 111 and 118.

Run the engine free to bring up steam pressure. If water discharges at 34 with less than 550 pounds, turn worm 38 to the left a turn at a time till the by-pass opens at 550 pounds. If water leaks slowly from 34 with lower steam pressure, valve 141 must be reground with fine pumice.

Rear Axle. The rear axle is ball bearing and is lubricated either with steam cylinder oil or with heavy gear case oil. About every thousand miles unscrew the bottom plug in the axle case and see whether the oil comes out, and whether the oil is clean. If so, fill the casing through the plug on the side near the bottom until it runs out from side plug. Occasionally wash out the casing with kerosene and fill with new oil.

The rear wheels are removed by slackening two clamp bolts, one above and one below at each end of the axle. The wheel shaft and bearing may then be drawn from the casing. To remove the wheel from the shaft, unscrew hub cap and lock nuts.

Brakes. Both foot and hand brakes act on the rear wheel drums and are compensated by steel cables. Adjustments are made by the turn buckles at the back ends of the brake shoes.

Condenser. Ordinarily steam does not escape into the air from the condenser, but there is a relief valve in the top which opens under internal pressure when the condenser has more steam than it can take care of.

To clean the condenser, remove the exhaust chamber or top header and the bottom header by undoing the nuts on the through bolts, thereby leaving the tubes exposed for cleaning without removing the condenser from the car.

Lubrication. Following are the makers' instructions regarding lubrication:

To insure a long life to the crank shaft and valve gearing it is necessary that it be properly lubricated, Fig. 61, and at least every five hundred miles the drain cock 68, Fig. 55, in the bottom of the crank case, should be opened and any water that has collected there drained out. This should be done when the engine is cold, as then the water will settle and is easily drained out. At this time the operator should make sure that there is sufficient oil in the crank case to lubricate thoroughly and if there is not, put in enough.

Once a month clean out the oil in the crank case and fill with new. To do this, put a pint or so of kerosene in the crank case and run the engine at moderate speed for five minutes and then open the drain cock and let it all run out. Fill with two quarts of clean oil.

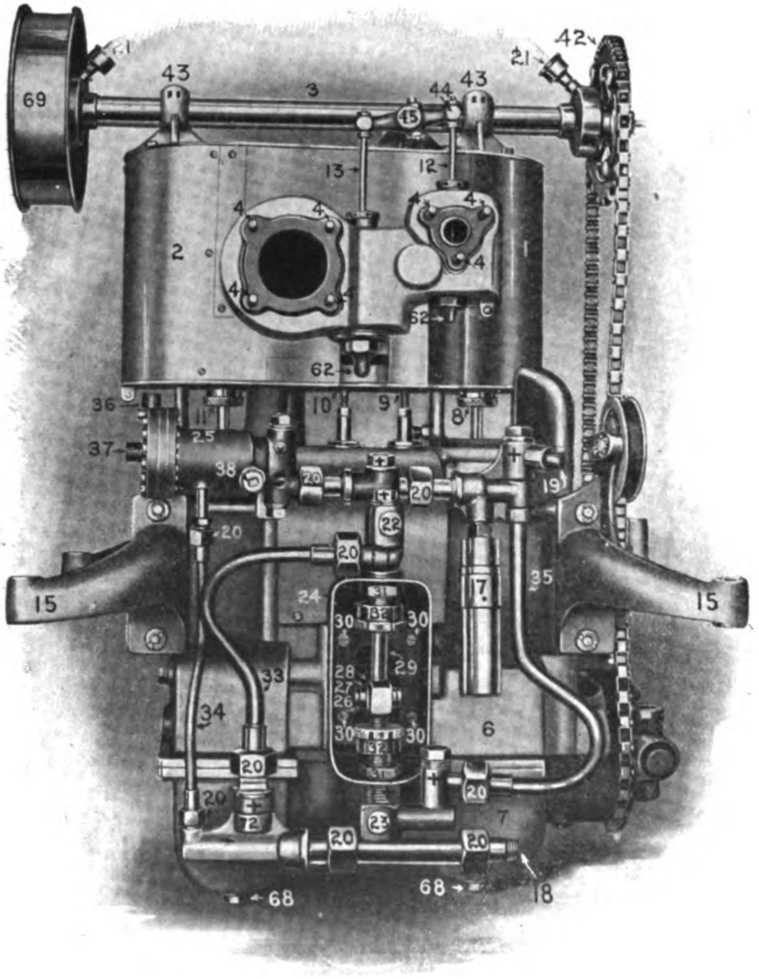


Fig. 62. Engine—Left-Side View, White—1907-1908.

A good grade of motor grease should be used in the grease cups and grease gun.

Care should be used to prevent dirt or grit mixing with either oil or grease.

Examine all oil connections for clogging or leaks.

The lubrication of the engine is principally automatic, the oiler being driven from the engine by a ratchet. Oilers are also provided with hand plungers Nos. 108 and 109, Fig. 57, and should be given a few strokes when starting.

Should the steam gauge needle vibrate, pump oil around the pipe line. Open valves 118 and 111, Fig. 49 and Fig. 51, and pump with cylinder hand oiler 108 until oil runs from valve 111. Always close valve 118 when through.

These directions are for running under ordinary conditions. When the conditions become unusual, as in heavy mud or long, dusty trips, the operator must use his judgment about increasing the lubrication of the exposed parts.

Flush the water tank daily and clean thoroughly once a week.

To Drain Water from Car. Raise the steam pressure and run the engine long enough to warm it thoroughly.

Disconnect the unions at the suction side of both water pumps 22 and 23, Fig. 47 and Fig. 53.

Disconnect pipe 127 at union 21, Fig. 47.

Disconnect pipe 130 at flow motor and thermostat and remove, Fig. 47.

Disconnect the condenser pipe line at 40, Fig. 53, and open pet cock at bottom of condenser.

Run the engine idle until the steam pressure is down to two or three hundred pounds and give hand water pump 99 a few strokes, also pump plenty of oil into the cylinders by means of lever 108, Fig. 57.

With the engine still running, open the blow-off valve which connects to the top of the generator located back of the water tank and reached through a hole in the running board shield by the tool box, then open blow-off valve 111, Fig. 49 and Fig. 51.

If the car is to be laid up for a long time it is well to remove balls from all checks.

To Drain by Air Pressure. The car can best be drained by means of air if air pressure is available.

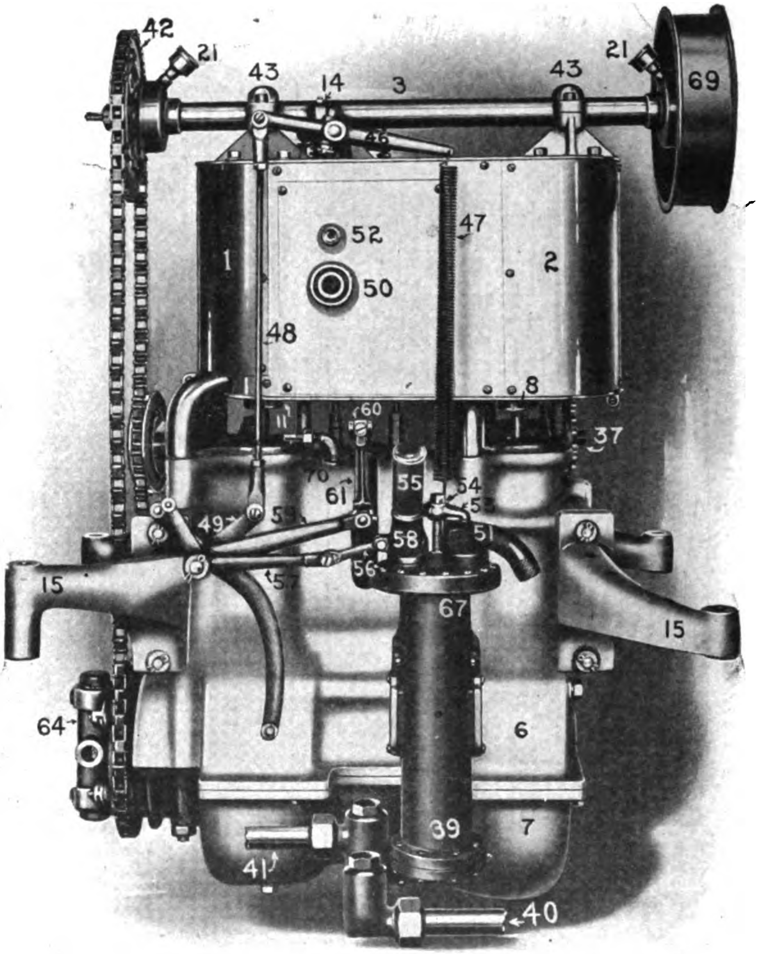


Fig. 63. Engine—Right-Side View, White—1907-1908.

Open the drip cock at the bottom of the condenser and disconnect condenser line at union 40. Remove the plug from the bottom of the water tank. Blow air through condenser line by applying at 40, Fig. 53.

Remove hose 18, Fig. 55, and apply air at union where 18 connects to pumps. Open blow-off valve 111 and water may all be forced through.

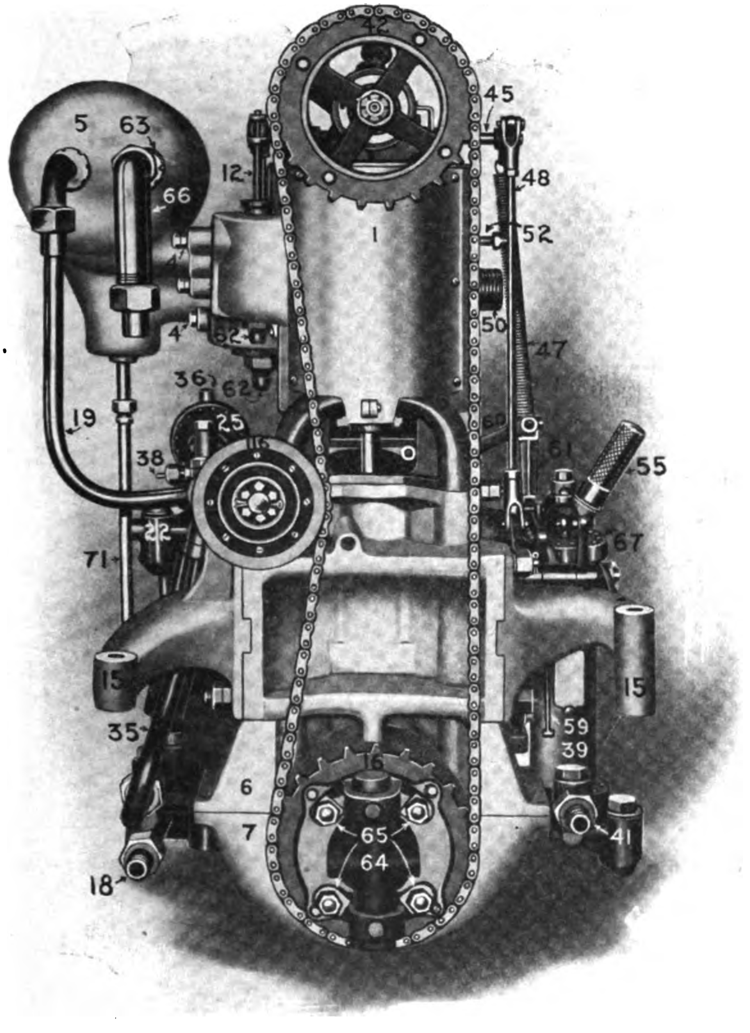


Fig. 64. Engine—Back-End View, White—1907–1908.

To Get Good Results. Care should be taken that all parts are well lubricated, the stuffing boxes packed, and all joints tight.

When the stuffing boxes begin to leak, it is advisable to take them up at once before the steam has a chance to wear a groove in the packing. When repacking remove all old packing then replace with new and watch for leaks until it becomes thoroughly settled. After once getting settled without the steam wearing a passage through it, the box will not have to be repacked for a long time. Don't keep valve stem stuffing boxes too tight as there is only exhaust steam against them.

Use 600-W Mineral or D Mobiloil.

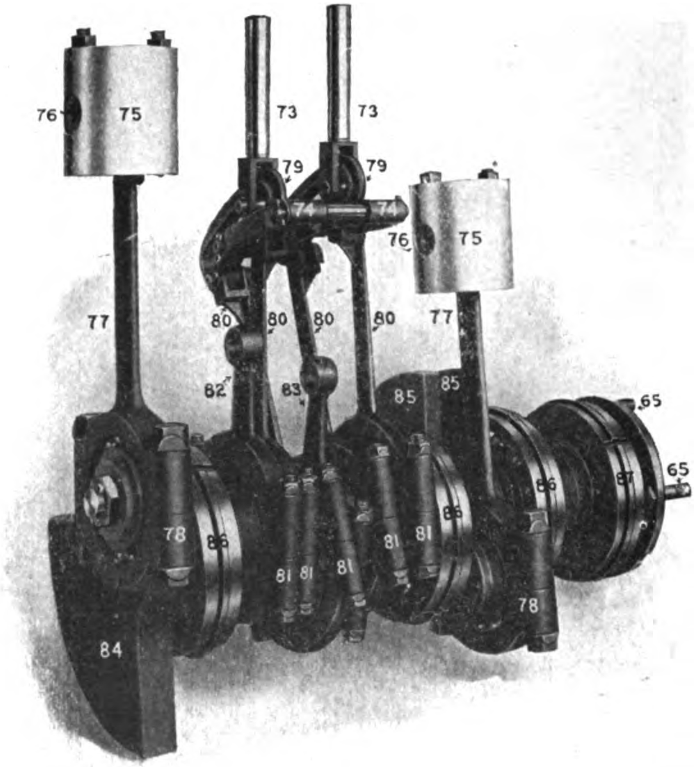


Fig. 65. Crank of Engine, White—1907–1908.

Keep the air pressure from 50 to 60 pounds—always above 50 pounds.

Do not crowd the car when starting. Give the engine time to warm up.

Do not try to run 70 miles per hour.

Do not try to make fast time on bad roads.

Do not overload the car; it is designed for five or seven passengers only.

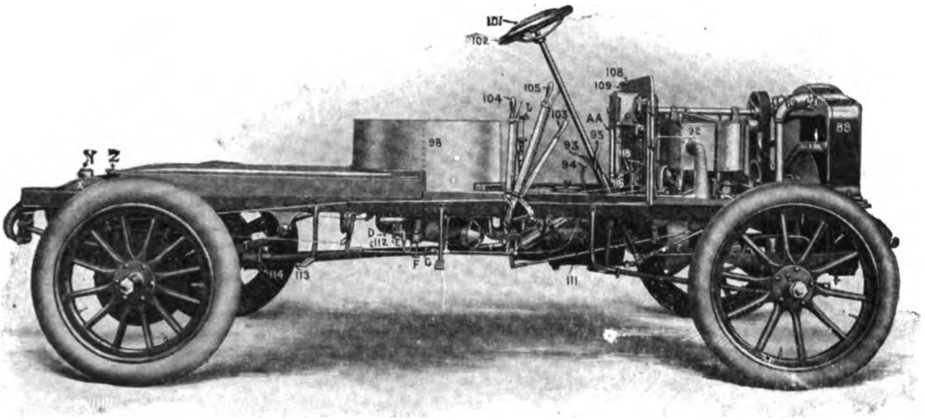


Fig. 66. Chassis—Side View, White—1907-1908.

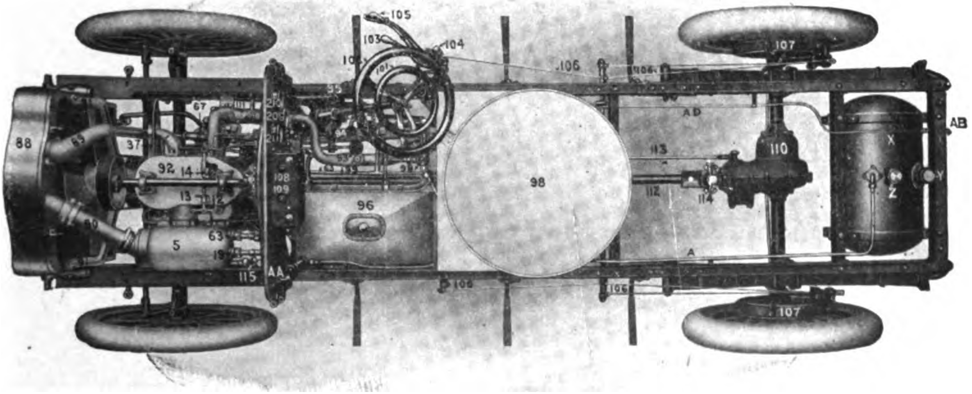


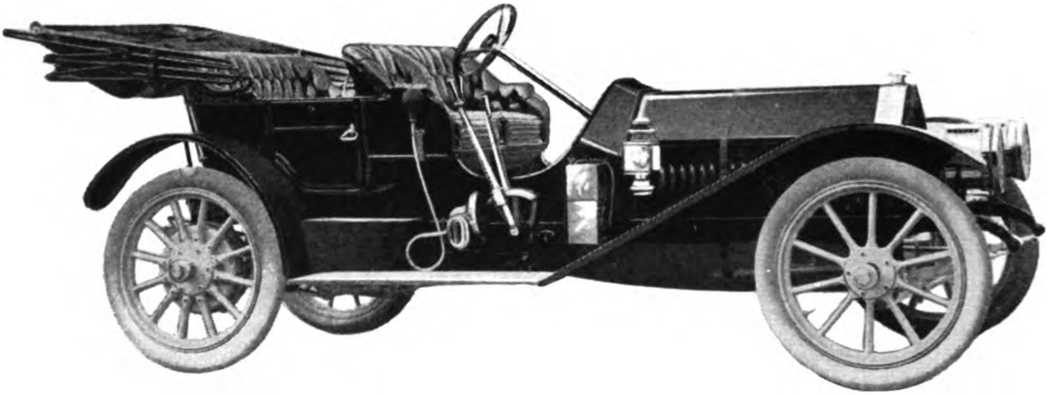
Fig. 67. Chassis—Top View, White—1907-1908.

Always close the throttle before applying brakes or reversing the engine.

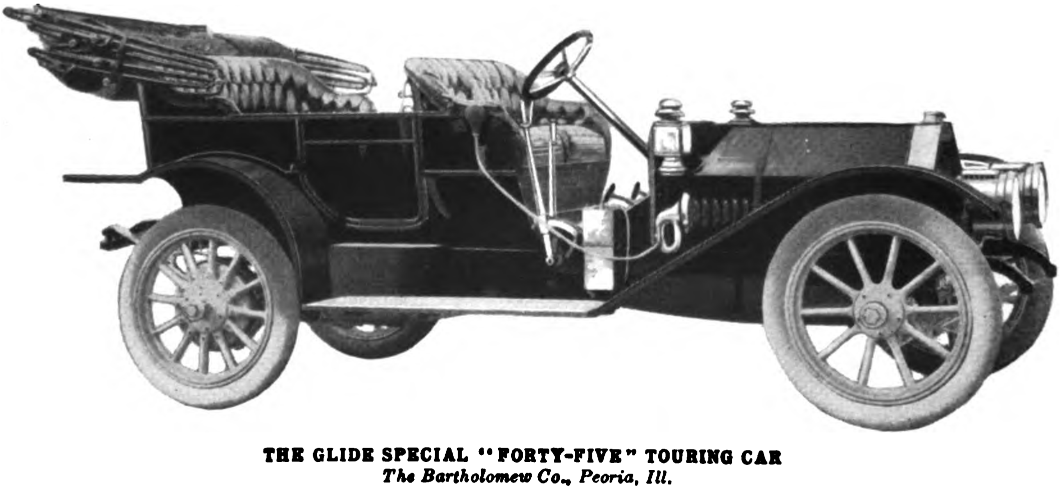
Always make it a practice to disengage the engine from running gear by means of lever 103 before leaving the driver's seat.

1907-8 WHITE CARS VS. 1909-10 MODELS

The 1907 to 1908 White cars were substantially similar to the present models as regards the essential features of the generator, burner, flow motor, thermostat, and water regulator. They use only one fuel (gasoline), but otherwise the instructions for firing up are identical. Slight changes appear in the form of the flow motor and the arrangement of the piping, but these in no way affect the management and adjustment. The engine is shown complete in end and side views in Fig. 62, Fig. 63, and Fig. 64. The burner nozzle of the later cars has three orifices, whereas that of the earlier cars has but one. The form of the air shutter on the mixing tube is also slightly changed. The chief difference between the earlier and later models relates to the engine itself, which in the former has the Stephenson link motion, illustrated in Fig. 65. As this type of valve gear has already been fully described no further explanation is necessary. The chassis arrangement is shown in Fig. 66 and Fig. 67.



THE GLIDE SCOUT
The Bartholomew Co., Peoria, Ill.



THE GLIDE SPECIAL "FORTY-FIVE" TOURING CAR
The Bartholomew Co., Peoria, Ill.

GLOSSARY

*INDEX TO NUMBERS AND LETTERS OF THE WHITE CARS

1907-1908

1	High-pressure cylinder
2	Low-pressure cylinder
3	Fan shaft casing
4	Feed water heater stud
5	Feed water heater
6	Engine casing
7	Crank case
8	High-pressure piston stuffing-box
9	High-pressure valve stuffing-box
10	Low-pressure valve stuffing-box
11	Low-pressure piston stuffing-box
12	Valve opening exhaust from high-pressure cylinder
13	Valve closing high-pressure exhaust from low-pressure steam chest
14	Valve admitting steam from high-pressure to low-pressure steam chest
15	Engine girt
16	Engine sprocket
17	Compression chamber
18	Suction from tank
19	Discharge pipe from pump to feed water heater
20	Unions in water connections
21	Grease cup
22	Upper power pump
23	Lower power pump
24	Power pump frame
25	Water regulator
26	Pump lever pin
27	Pump lever
28	Pump block
29	Pump plunger
30	Screws attaching pump frame to engine
31	Power pump lock nuts
32	Power pump stuffing-boxes
33	Upper power pump suction pipe
34	Water regulator by-pass pipe
35	Discharge pipe of lower power pump
36	Steam gauge and oil connection of water regulator
37	Steam connection of water regulator
38	Water regulator adjusting worm

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*To enable the student to pick out and identify the parts of the White cars, these are listed in full with reference numbers corresponding to the illustrations.

39 Condenser pump
40 Condenser pump suction end
41 Condenser pump discharge end
42 Fan shaft sprocket
43 Fan shaft casing support
44 Simpling valve rocking lever
45 Simpling valve rocking lever shaft
46 Simpling valve rocking lever (spring side)
47 Simpling valve lever spring
48 Simpling valve lever connecting rod
49 Simpling valve bell crank
50 Main steam connection to high pressure steam chest
51 Engine air pump discharge connections
52 Cylinder oiler connection
53 Engine air pump yoke
54 Engine air pump yoke bolt
55 Engine air pump strainer
56 Air pump regulating lever
57 Air regulating lever bell crank
58 Air pump suction check chamber
59 Bell crank connecting to reverse arm
60 Reverse arm
61 Connecting rod reverse arm to bell crank
62 Simpling valve cap
63 Discharge from feed water heater to flow motor
64 Engine universal joint
65 Bolts holding universal joint to crank shaft
66 Feed water strainer casting
67 Engine air pump
68 Plug for draining crank case
69 Fan shaft pulley
70 Crank case oiler connection
71 Feed water heater drip to condenser
72 Upper power pump suction check casting
73 Valve stem bearings
74 Link yoke
75 Crosshead
76 Crosshead pins
77 Connecting rod
78 Connecting rod cap
79 Valve links
80 Eccentric rods
81 Eccentric rod cap
82 Air and condenser pump eccentric rod
83 Water pump eccentric rod
84 Counterbalance low pressure
85 Counterbalance high pressure
86 Main bearing
87 Main thrust bearing

88	Condenser
89	Condenser overflow
90	Exhaust pipe
91	Fan bracket
92	Engine
93	Pedal operating simpling valve
94	Pedal operating air pump valve
95	Pedal operating foot brake
96	Water tank
97	Water regulator washer
98	Generator
99	Hand water pump
100	Pipe from 63 to thermostat
101	Throttle wheel
102	Steering wheel
103	Emergency gear lever
104	Reverse lever
105	Brake lever
106	Brake cables
107	Brakes
108	Cylinder oiler
109	Crank case oiler
110	Gear case
111	Blow-off valve
112	Driving shaft
113	Emergency gear rod
114	Universal joint (rear)
115	Air line check valve
116	Fan shaft chain idler
117	Universal joint (front)
118	Oil valve to water regulator
119	Thermostat valve stem cap
120	Flow motor
121	By-pass pipe to tank
122	Thermostat casting
123	Flow motor inlet
124	Flow motor outlet
125	Stuffing-box
126	Upper blow-off valve
127	Pipe to generator
128	Generator inlet
129	Discharge to engine
130	Pipe from thermostat to motor discharge
131	Connection to feed water heater
132	Main casting
133	Water regulator cover
134	Diaphragms
135	Plug
136	Diaphragm shifting pad

137	Plunger
138	Spring
139	Lock nut for plunger adjustment
140	Lever
141	Valve
142	Spring adjusting nut
143	Spring adjusting pad
144	Valve seat
145	Connection to pump discharge
146	Pinion driving shaft
147	Emergency gear shaft
148	Driving spur gear
149	Spur gear
150	Internal spur gear 149
151	External spur gear 149
152	Large spur gear on emergency shaft
153	Small spur gear on emergency shaft
154	Driving pinion
155	Pinion shaft rear bearing
156	Rear axle bearing
157	Pinion shaft front bearing
158	Oil cup
159	Roller bearing
160	Shifting lever groove
161	Shifting lever groove
162	Exhaust inlet
163	Throttle bracket
164	Fan
165	Fan pulley
166	Connection to condenser pump
167	Drip cock
168	Top of condenser
169	Bottom of condenser
170	Condenser side frame
171	Hood support bracket
172	Throttle casting
173	Nickel seat
174	Throttle stem
175	Union nut
176	Throttle sleeve
177	Throttle lever
178	Stuffing-box nut
179	Stuffing-box gland
180	Projection on valve stem
181	Valve seat
182	Connection to engine
183	Connection to generator
184	Passage through throttle seat
185	Brake drum

186	Foot brake band
187	Emergency brake band
188	Foot brake spring
189	Foot brake turn buckle
190	Emergency brake turn buckle
191	Piston
192	Piston rod
193	Valve stem
194	Valve stem lock nut
195	Groove
196	Plug for draining
197	By-pass valve
198	Flow motor piston spring
199	Thermostat casting
200	Water inlet
201	Valve stem
202	Valve stem adjusting nut
203	Valve stem seat
204	Water outlet
205	Bell crank
206	Bell crank spring
207	Element of thermostat
208	Union nut holding pyrometer in thermostat casting
209	Vaporizer pressure gauge
210	Steam-pressure gauge
211	Air-pressure gauge
212	Valve stem stuffing-box
213	Valve end thermostat element stuffing-box
214	Pyrometer end thermostat element stuffing-box
215	Thread securing thermostat element in casting
216	Steam entrance to thermostat casting
217	Steam outlets from thermostat casting
218	Outside element of pyrometer
219	Inside element of pyrometer
220	Metal cap extension on inside element
A	Supply pipe from fuel tank
AA	Hand air pump
AB	Main fuel shut-off valve
AC	Flow motor stuffing-box
AD	Pipe from power air pump
B	Fuel strainer casting
C	Fuel strainer plug
CA to CD	Graduation valve stem
CB	Plug
D	Main sub-burner valve
E	Sub-burner flush valve
F	Sub-burner adjusting valve
G	Warming up valve
H	Pipe to main burner valve

HA	Pipe connecting valve G with vaporizer N
I	Pipe to warming up valve
J	Main burner valve
K	Fuel pipe to flow motor
L	Flow motor fuel valve
M	Pipe from flow motor fuel valve to vaporizer
MA	Sub-burner supply pipe.
N	Vaporizer
NA	Vaporizer discharge pipe
O	Vaporizer nozzle
P	Sub-burner cap
Q	Burner
R	Burner induction tube
S	Induction tube shutter
T	Pipe to vaporizer gauge
U	Vaporizer support post
V	Sub-burner casing
W	Sub-burner casing door
X	Fuel tank
Y	Fuel tank filler cap
Z	Fuel tank gauge

1909-1910

1	High-pressure cylinder
2	Low-pressure cylinder
3	Valve gear inspection plate
4	Water pump inspection plate
5	Feed water heater
6	Engine casing
7	Crank case inspection plate
8	High-pressure piston stuffing-box
9	High-pressure valve stuffing-box
10	Low-pressure valve stuffing-box
11	Low-pressure piston stuffing-box
12	Intercepting valve (simpling valve mechanism)
13	Relief cocks
14	Pass-over valve (simpling valve mechanism)
15	Air and condenser pump inspection plate
16	Fan pulley
17	Compression chamber
18	Suction from tank
19	Discharge from pumps to flow motor
20	Unions in water connections
21	Union connecting pipe 127 to hand water pump 99
22	Upper power pump
23	Lower power pump
24	Power pump frame

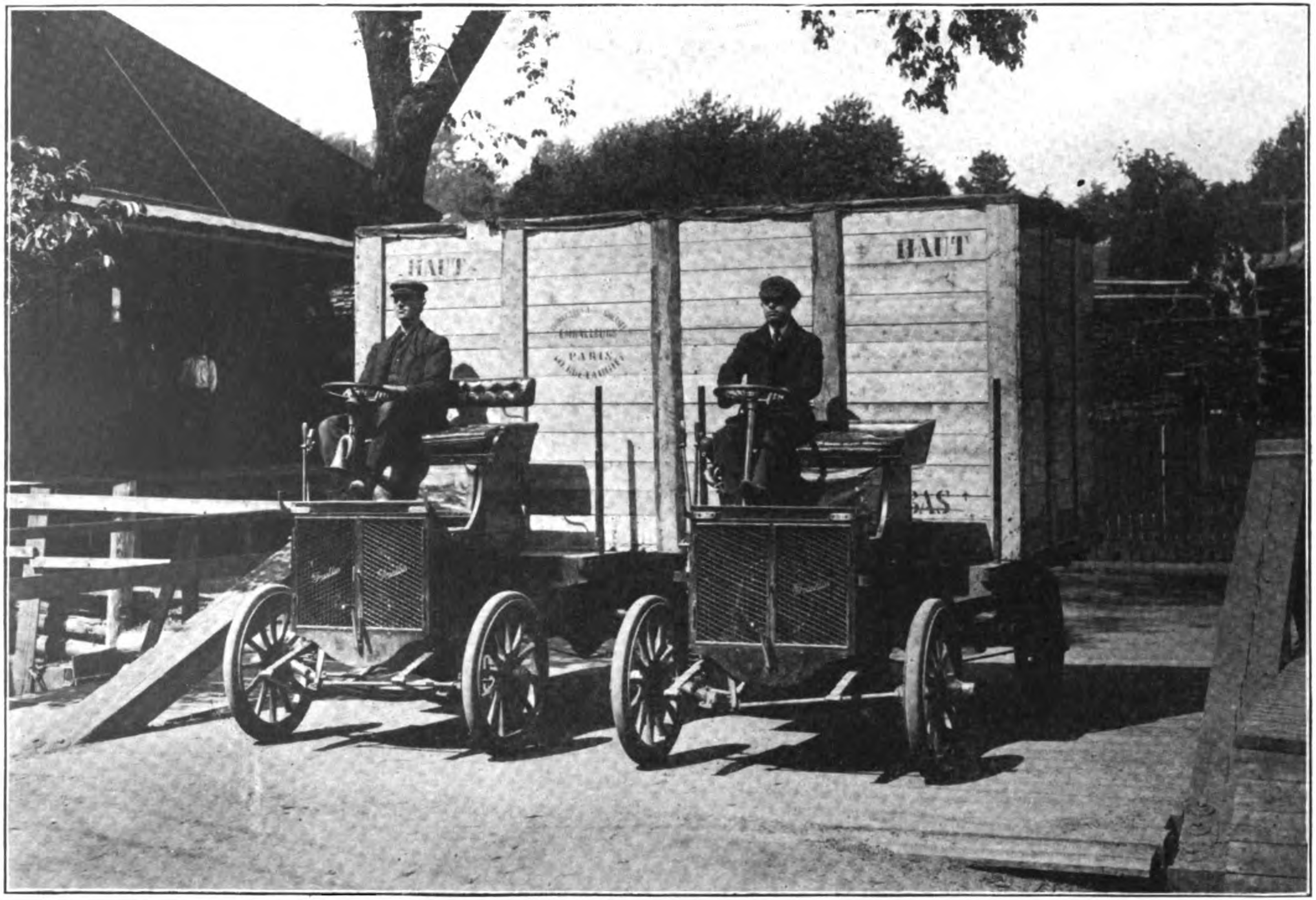
25 Water regulator
26 Pump block pin
27 Pump lever
28 Pump block
29 Water pump plunger
30 Screws attaching pump frame to engine
31 Power pump lock nuts
32 Power pump stuffing-boxes
33 Upper power pump suction pipe
34 Water regular by-pass pipe
35 Discharge pipe of lower power pump
36 Steam gauge and oil connection
37 Steam connection of water regulator
38 Water regulator adjusting worm
39 Condenser pump
40 Condenser pump suction end
41 Condenser pump discharge end
42 Pyrometer
43 Relief cock lever
44 Simpling valve lever
45 Emergency tank air valve
46 Steering gear casing
47 Lever operating automatic oiler
48 Piston head
49 Piston rings
50 Steam connection to high pressure steam chest
51 Engine air pump discharge connection
52 Cylinder oiler connection
53 Exhaust inlet to feed water heater
54 Exhaust outlet from feed water heater to condenser
55 Engine air pump strainer
56 Air pump regulating lever
57 Crank case stuffing-boxes
58 Valve crosshead
59 Piston rod
60 Reverse arm
61 Valve gearing levers
62 Crank-shaft
63 Crank-shaft lock ring
64 Universal joint, engine end driving shaft
65 Bolt holding universal joint to crank shaft
66 Crank-shaft lock washer
67 Engine air pump
68 Cock for draining crank case
69 Ball separator rings
70 Crank case oiler connection
71 Valve slides
72 Valve slide rollers
73 Valve stem

74 Low pressure piston valve
75 Piston crosshead
76 Crosshead pin
77 Connecting rod
78 Valve slide frame
79 Air pump cable guide
80 Engine support
81 Screws holding valve slide frame in engine frame
82 Cut-off pedal adjusting pin
83 Water line from flow motor to feed water heater
84 Counterbalance
85 Water drain from feed water heater
86 Main bearing
87 Water tank strainer casting
88 Condenser
89 Condenser overflow
90 Condenser exhaust pipe
91 Pedal regulating cut-off
92 Engine
93 Pedal operating simpling valve
94 Pedal operating air pump valve
95 Pedal operating foot brake
96 Water tank
97 Water regulator washer
98 Generator
99 Hand water pump
100 Pipe from 19 to thermostat
101 Throttle wheel
102 Steering wheel
103 Emergency gear lever
104 Reverse lever
105 Brake lever
106 Brake cables
107 Brakes
108 Cylinder oiler pump
109 Crank case oiler pump
110 Gear case
111 Blow-off valve
112 Driving shaft
113 Emergency gear rod
114 Universal joint (axle end of driving shaft)
115 Air line check valve
116 Rear axle inspection plate
117 Main driving gear
118 Oil valve to water regulator
119 Thermostat valve stem cap
120 Flow motor
121 By-pass pipe to tank
122 Thermostat casting

123	Flow motor inlet from pumps
124	Flow motor outlet
125	Flow motor stuffing-box
126	Suction for hand water pump
127	Pipe to generator
128	Generator inlet
129	Discharge to engine
130	Pipe from thermostat to flow motor discharge
131	Feed water heater drain inlet
132	Water regulator main casting
133	Water regulator cover
134	Diaphragms
135	Plug
136	Diaphragm shifting pad
137	Plunger
138	Spring
139	Lock nut for plunger adjustment
140	Lever
141	Valve
142	Spring adjusting nut
143	Spring adjusting pad
144	Valve seat
145	Connection to pump discharge
146	Pinion driving shaft
147	Emergency gear shaft
148	Sliding spur gear on pinion shaft
149	Spur gear
150	Internal spur gear (149)
151	External spur gear (149)
152	Large spur gear on emergency shaft
153	Small spur gear on emergency shaft
154	Driving pinion
155	Pinion shaft rear bearing
156	Rear axle bearing
157	Pinion shaft front bearing
158	Oil cup
159	Roller bearing
160	Shifting lever groove
161	Shifting lever groove
162	Exhaust inlet
163	Flow motor inlet from thermostat
164	Fan
165	Differential gear casing
166	Connection to condenser pump
167	Air and condenser pump plunger
168	Top of condenser
169	Bottom of condenser
170	Condenser side frame
171	Rear axle clamp bolt

172	Throttle casting
173	Nickel seat
174	Throttle stem
175	Union nut
176	Throttle sleeve
177	Throttle lever
178	Stuffing-box nut
179	Stuffing-box gland
180	Projection on valve stem
181	Valve stem seat
182	Connection to engine
183	Connection to generator
184	Passage through throttle seat
185	Brake drum
186	Foot brake band
187	Emergency brake band
188	Foot brake spring
189	Foot brake turn buckle
190	Hand brake turn buckle
191	Flow motor piston
192	Piston rod
193	Valve stem
194	Valve stem lock nut
195	Grade water groove
196	High pressure piston valve
197	By-pass valve
198	Flow motor piston spring
199	Thermometer well
200	Water inlet of thermostat
201	Thermostat valve stem
202	Valve stem adjusting nut
203	Valve stem seat
204	Water outlet
205	Bell crank
206	Bell crank spring
207	Element of thermostat
208	Union nut holding pyrometer in thermostat casting
209	Air and vaporizer pressure gauge
210	Steam pressure gauge
211	Steam line to thermostat
212	Valve stem stuffing box
213	Thermostat element stuffing-box
214	Steam line from thermostat
215	Thread securing thermostat element in casting
216	Steam entrance to thermostat casting
217	Steam outlet from thermostat casting
218	Inside element of pyrometer
219	Outside element of pyrometer
220	Metal cap extension on inside element

A	Supply pipe from fuel tank
AA	Hand air pump
AB	Main fuel shut-off valve
AB2	Emergency fuel tank shut-off valve
AC	Flow motor stuffing-box
AD	Pipe from power air pump
B	Fuel strainer casting
C	Fuel strainer plug
CA to CD	Graded fuel valve stem
CB	Flow to motor fuel valve plug
D	Main sub-burner valve
E	Tee connecting tank X2 into fuel line A
F	Sub-burner adjusting valve
G	Warming up valve
H	Pipe to main burner valve
HA	Pipe connecting valve G with vaporizer N
I	Pipe to warming up valve
J	Main burner valve
K	Fuel pipe to flow motor
L	Flow motor fuel valve
M	Pipe from flow motor fuel valve to vaporizer
MA	Sub-burner supply pipe
N	Vaporizer
NA	Vaporizer discharge pipe
O	Vaporizer nozzle
P	Sub-burner cap
Q	Burner
R	Burner induction tube
S	Induction tube shutter
T	Pipe to vaporizer gauge
U	Vaporizer support post
V	Sub-burner casing
W	Sub-burner casing door
X	Fuel tank
X2	Emergency fuel tank
Y	Fuel tank cap
Y2	Emergency fuel tank cap
Z	Fuel tank trycocks



AUTOMOBILE-TRUCK PONTOON FOR HANDLING BOXED MOTOR CARS

Novel Method Employed by the H. H. Franklin Mfg. Co. in Handling with Their One-Ton Trucks a Crated Automobile Weighing 4050 Pounds.

COMMERCIAL VEHICLES

PART I

INTRODUCTION

Much wonderment is frequently expressed at the comparatively slow development of the motor-driven vehicle for commercial usage in this country, and this is increased when it becomes known that the actual advent of the business automobile took place not very long after that of its rival—the pleasure car—which has since monopolized the center of the stage. But the underlying reasons are neither numerous nor complex. Reliability is naturally the chief essential in commercial service and this was possessed in no great degree by the early models of the present day commercial vehicles —probaby less so than was the case with the pleasure car. Huge sums of money are tied up in horse-drawn equipment and the average business man naturally hesitates to change—in fact, it is but a repetition of the history of the horse and the trolley car. It is only a question of a few years when the power wagon will have displaced its predecessor quite as generally as has electric traction the horse car in street-railway service.

It is important to know the reasons for the revolution that is now in active progress, as well as to become familiar with the prevailing practice in America and abroad, in the construction, operation, and maintenance of that large and varied class of automobiles which is employed exclusively for business purposes. Regardless of type, class, or method of propulsion these are commonly referred to as *commercial vehicles*. This classification embraces not alone motor delivery wagons and trucks for the transportation of merchandise, but likewise taxicabs, omnibuses, sight-seeing vehicles, motor road trains, farm tractors, emergency repair or tower wagons for street-railway service, and also special municipal service vehicles—ambulances, patrol wagons, fire engines, street sprinkling and garbage removal wagons and the like. In fact, it may be said that any auto-

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mobile not devoted to pleasure is a commercial vehicle, and as was naturally expected, the first commercial vehicles were merely pleasure cars transformed to suit the needs of the occasion. To a certain extent, this still continues to be the case.

Standard Design. Whether it be electric-, steam-, or gasoline-driven, the general design of the motive power as well as that of its transmission to the driving wheels is practically the same in the commercial vehicle as it is in the pleasure car. All of the component parts of the latter—bearings, frames, axles, steering gear, and compensating mechanism—have their counterparts in every industrial vehicle. In other words, the chassis in either case is composed of similar members. For the sake of brevity in the present treatise, it is assumed at the start that the reader has become familiar with motor-car engineering in so far as it relates to pleasure-car construction; that he understands from previous study and actual handling of machines, the theory of the operation of the internal combustion engine; that he is conversant with the distinguishing characteristics of the several types of engines as well as their advantages and limitations; and that he is acquainted with the types of transmission systems ordinarily employed on pleasure cars—in brief, that he understands any reference to component parts, their functions and their relation to one another, without the necessity of explanation.

In common with the pleasure car, the commercial vehicle is capable of traveling at various speeds wherever road conditions will permit it to go. Both comprise in a single entity, a wheeled vehicle suitable for transportation purposes, fitted with an independent, self-contained power-plant. To this extent, they both present the same engineering problems in so far as they relate to the construction of the motor, its control, and the transmission of its power to the road wheels, the design of the running gear, and the control of the vehicle itself. Divergence in practice is encountered with the consideration of the purposes for which each vehicle is designed. The pleasure car is not intended to be a particularly efficient vehicle. Its carrying capacity bears but a comparatively insignificant ratio to its total weight, and the car is not usually designed to work under the same severe and continued conditions of service which are the first requirement of the commercial vehicle. It must be capable of high speed with its maximum load of passengers and must combine reliability with endurance to a sufficient extent to meet the demands of its owner on pleasure bent. A little consideration of these factors may throw some light on the difficulty which was encountered in previous years in convincing the enthusiastic motorist that automobiles would be a *paying investment* in his business.

Requirements in Commercial Field. Reliability is naturally the prime essential in the business vehicle; then come efficiency, economy, and endurance. The combination of these three qualities make it so superior to horse traction as to admit of no comparison in the results obtainable. The accomplishment of the first-named has naturally been the outcome of years of experience in the development of the pleasure car and the application to the commercial vehicle, of the lessons thus learned. Until this was achieved, it was naturally difficult for the motor vehicle to compete with its time-tried, though slow and inefficient, predecessor. Efficiency means the maximum weight of the useful load transported, in proportion to the weight of the vehicle itself; this element also involves economy, as the vehicle and its load must be moved at a speed greater than is possible with horses. To meet these difficult requirements, it is necessary, first, to provide a self-propelled vehicle in which the nicest possible proportion of vehicle weight to maximum useful load capacity is realized; second, to employ a motor of sufficient power and suitable speed reduction through its transmission to the road wheels that will enable the machine to ascend the steepest grades with full load, and yet not overburden the machine with superfluous weight or power for safe and reasonable speeds on the level; and third, to proportion every part so as to insure the longest life to the vehicle and the greatest economy in its use. It is not the province of the present treatise to discuss these problems and their solution from the engineer's viewpoint, but to consider the machines as they are at present built in this country for the benefit of the user. This term is intended to apply to the driver and the traffic department head, quite as much as the merchant who looks upon the adoption of the power wagon solely in the light of an investment.

The keynote to the successful commercial vehicle is reliability and economy in operation. It must compete with all other forms of transportation—carrying merchandise or passengers quicker and cheaper per ton mile or per passenger mile than the horse-drawn vehicle, and either cheaper or quicker, or with greater convenience in many cases than the railroads, this phase of the problem naturally only involving short hauls. When it is borne in mind how easily anything in the form of a pleasure automobile has been marketed during the past five to eight years, it will be apparent why manufacturers generally were loth to attempt the solution of the commercial vehicle problem. To put it bluntly, "There was no money in it," and the task was a thankless one. Not that the possibilities were unthought of. The pioneer automobile builders realized the great promise of the future for the motor delivery wagon, truck, and bus, quite as fully at the outset, as their confrères do today. In fact, in this country the first general use of the electric vehicle—the cab—was for purely commercial purposes. Not a few electric and steam vehicles were built for business purposes during the period from 1897 to 1902—a time which the modern motorist regards as the dark ages. There were also a small number of gasoline-driven commercial cars constructed during the period in question, and some of them have been rendering service steadily ever since. It is needless to add that they represent a bright exception, as the internal-combustion engine for vehicle use was then in the primary stages of its development and the patience required to perfect it called for more persistent effort than many were capable of.

Imperfect Service Brings Reaction. As is inevitable when anything is placed on the market in a crude state, a reaction will follow its adoption as soon as its shortcomings make themselves apparent. Inventors and manufacturers naturally could not afford to perfect the commercial machine at their own expense. As was the case with the pleasure vehicle, the buyer had to bear the burden of experimental expense. Early commercial vehicles, as a consequence, fell shorter of materializing their purchasers' expectations than did the pleasure cars, for the former were intended to show a definite return on the credit side of the balance sheet, while in the latter case, expense was only a thing to be reckoned with when it exceeded the purse of the car's owner. Over-light construction was the chief structural defect of the first steam vehicles in this country, while it did not take long to demonstrate that steam, in the manner then employed, was not the long-sought power for commercial use. As a result, the fire-tube boiler type of steam car disappeared almost completely. Excessive weight in proportion to load capacity, marked inefficiency and excessive depreciation of the batteries, these were some of the discouraging features encountered in the attempt to electricity through the medium of the storage battery. The almost utilize entire absence of the factor of reliability in service settled the score of the gasoline-driven machine. Add to the above the fact that repairs and replacements were an unduly large proportion of the expense in every case, and that the vehicles were frequently out of service, and it will be easy to understand why merchants generally did not enthuse over the commercial motor vehicle.

Reliable Gasoline Car Solves Difficulty. It was really not until the gasoline-driven pleasure car had arrived at a point where it could be depended upon to give satisfaction in the hands of the ordinary driver, that interest in its commercial possibilities reawakened. Attempts to utilize the electric vehicle had been continued in the interim, and, in the aggregate, quite a number of these machines were turned out, many of them still being in active service. But the number of manufacturers devoting attention to this branch was very small, and it has only been in comparatively recent years that any decided progress has been made. Strange as it may seem, successful builders of gasoline pleasure cars have not been responsible, as a whole, for the development of the commercial vehicle. When attention was again turned to this field after the period of inaction, a new group of manufacturers came into existence. Then, with the lessening need of experimental work on the pleasure car, builders of the latter again took up the commercial side seriously, so that it is safe to say that today, there is scarcely an automobile manufacturer in the country that is not either actually producing commercial vehicles or contemplates doing so in the immediate future.

Generally speaking, this second stage in the development of the motor-driven industrial vehicle, which is now in full swing, had its inception about 1905. Since then, the number of manufacturers devoting attention to the gasoline type has increased so rapidly that the makers of electric and steam cars combined, form but an insignificant fraction of the total. In fact, there is but one American manufacturer doing any considerable business in steam-powered commercial vehicles. In England, the latter have met with considerable success, particularly for heavy haulage purposes, but there has been little attempt made to introduce them here and the few that have actually been tried have been unsuccessful. Electric vehicles still hold their own and are being produced in larger numbers than ever, but there has been no increase in the number of makers turning them out. There are now possibly a dozen, all told, building electric delivery wagons and trucks, and the prospect of any further increase in this direction appears remote. As compared with this showing of the present output of the two types that originally monopolized the commercial field to a very large extent, there are now half a hundred or more well-established manufacturers of gasoline commercial vehicles and additions to the ranks are frequent.

Classification. In order to make the subject as clear as possible, and facilitate reference on the part of the reader, industrial motor vehicles as a whole have been classified, first, by their motive power, and second, by the uses for which they are intended. Thus there are, in the order of their relative importance today:

Motive Power
- Gasoline-driven vehicles
- Electric vehicles
- Gas-electric vehicles
- Steam vehicles

Types of Vehicles
- Delivery wagons
- Trucks, vans, and similar freight carriers
- Passenger vehicles—stages, buses, taxicabs, sight-seeing cars, etc.
- Municipal vehicles—patrol wagons, ambulances, fire apparatus, garbage removal wagons, street sprinklers, etc.
- Special types—railway tower wagons, emergency repair wagons, vacuum cleaning outfits, farm tractors, road trains, etc.

This classification has been made advisedly, for though kerosene and alcohol are being experimented with as fuels for the internal combustion engine, and particularly for commercial purposes, by far the great majority of types marketed at present are driven by gasoline fuel.

Each of the foregoing principal divisions is susceptible of further subdivision, but this is neither necessary nor desirable. Commercial motor vehicles are now built for almost every conceivable purpose involving the haulage of freight or the transportation of passengers, including many special uses, such as hauling huge reels of telephone cable and drawing the cable through the underground conduits, transporting safes and pianos and hoisting them, delivering coal with special dumping wagons, and the like. They differ only in the special equipment with which they are provided for the service in view and as their construction otherwise is the same, it would only lead to confusion to attempt to consider them separately.

ELECTRIC VEHICLES

Though no longer a predominant feature of the commercial vehicle situation in this country, as the electric machine was the first type to score any considerable success in the commercial field, it is appropriate that it should be taken up first. It has been freely predicted in the past that the electric vehicle would disappear entirely with the development of the gasoline-driven machine, and there are still those who are of the same opinion today. In view of the startling evolution of the automobile industry as a whole in the past few years, it would be folly to attempt to predict what the ensuing decade may bring forth, but it seems safe to say that the electric will continue to fill the rôle in which it has proven so successful, for some time to come. It has a field all its own, and, up to the present, other types have not been able to invade the field to any extent, this being quite as true of the pleasure car as of its commercial confrère.

Advantages. One of its chief advantages from the purely commercial point of view, is its great simplicity, which to a very large extent solves the labor question that has proved such a deterrent to the adoption of the gasoline vehicle for commercial service. As the duties of the driver of an electric vehicle do not extend beyond its actual starting, stopping, and guidance while under way, anyone who has been accustomed to the use of horses can master its operation in the course of a few hours. This also appears to be equally true of men who have never driven any type of vehicle previous to their taking the wheel or steering tiller of an electric. Apart from the actual mechanical control of the vehicle, the driver's only other care is to keep informed as to the state of charge of the battery by watching the voltmeter, in order to prevent running the car with the batteries in an exhausted condition, as this is very detrimental to their continued usefulness. However, as most commercial vehicle batteries are charged every twenty-four hours and the car's run is planned to lie within its traveling radius on a single charge, with a factor of safety allowed in addition, this is not a very onerous duty. The further requirement of noting the current consumption on starting and running, as indicated by the ammeter, in order that any defect in the operation of the running gear of the car may be detected and remedied, is also a very simple one, so that an unskilled driver is available at a correspondingly lower charge for labor cost in the operation of the vehicle.

Power Efficiency. The amount of power available on a single charge of the batteries without unduly increasing the weight is so limited, that in the design of the electric great care must be taken to eliminate friction and other sources of power loss at every possible point. This is further necessitated by the gradually decreasing efficiency of the batteries with age. Starting at 80 per cent efficiency when new, this may rapidly drop to 50 per cent or below, unless the batteries are properly maintained, and this is likewise true of the transmission efficiency of the running gear of the vehicle, so that while unskilled labor may be employed for the operation of the vehicles, this is not the case where their maintenance is concerned. Power losses due to the tires are also an important factor, and as the pneumatic can very seldom be considered for commercial service, the same degree of efficiency is not obtainable from the business electric wagon as from the pleasure type employing the same motive power. Road conditions must also be considered, despite the fact that electrics are employed almost exclusively for city or near by suburban service, as mud, snow, and ice in winter, and poor pavements at any time, cause an increase in the current consumption.

It is safe to say that if improvements in design had not been effected as the result of experience, the electric vehicle would now have been practically eliminated as a factor of importance in the commercial vehicle situation, as the early types were extremely wasteful of power. One of the many reasons for this was the employment of two motors, which were at first considered necessary. It was found that the substitution of a single unit of slightly less capacity than the combined power of the pair previously employed was a long step in advance where power saving was concerned, and the practice of using but one motor even on comparatively heavy vehicles is now generally followed. This also served to cut down transmission losses, though it involved the use of a balance gear, or differential, to take the place of the independent drive to each rear wheel that was in vogue when two motors were used. The abandonment of a spur-gear drive in favor of chains was also a further improvement in the same direction. This made possible the removal of the motor from proximity with the driving wheels, to a point on the chassis where its weight could be better supported by the springs, thus effecting a step in advance on the score of maintenance as the motive power was no longer subjected to the severe pounding.

ELECTRIC DELIVERY WAGON

Whether considered from the point of view of design and construction, or from that of operation, the electric delivery wagon is without doubt the simplest vehicle in the commercial field. As already mentioned, its operation may be mastered in a comparatively short time, either by the ex-horse driver, or by a person who has never had any experience in the control of a vehicle, so that the labor cost—always an item of importance in this field—may be materially reduced without fear of the equipment suffering in consequence. It will be noted under on "Electric Trucks," Page 22, that it is customary with manufacturers of these vehicles to adopt a standard form of design, which is employed throughout in every size listed by the same maker, the only differences being those of dimension, load capacity of the vehicle, and capacity of the battery to take care of the increased weight.

This is likewise the case where electric delivery wagons are concerned. For instance, all the Studebaker delivery wagons are characterized by the same feature of design, except the one rated at 500-pounds capacity which is intended for very light work. This car is equipped with a single, high-speed electric motor, placed forward under the body and arranged to drive the rear wheels through a countershaft and chains. All the others are equipped with two motors which are placed near the rear wheels and drive the latter by countershafts, roller chains, small sprockets on the ends of the armature shafts and large ones bolted to the driving wheels.

Package delivery wagons and express wagons of the electric type have a useful load capacity ranging from 500 to 2,000 pounds, though very few of less than 1,000-pounds capacity are now built or employed. They are designed for maximum speeds of 10 to 15 miles an hour under favorable conditions on the level, and are fitted with batteries permitting of a maximum traveling radius of 40 to 50 miles on a single charge. The 40-mile run is standard and is based on an average speed of 10 to 12 miles an hour, including stops, as the necessity for frequently stopping and restarting the car in delivery service has an important bearing on the mileage of which the car is capable on a single charge. The latter is naturally figured on the maximum efficiency of the car as a whole, so that in practice this is seldom fully realized, due to the deterioration of the batteries in service. Consequently, while there are numerous instances on record of vehicles doing 40 miles a day or better, 25 to 30 miles will more nearly represent an average figure.

Design. The design of many of the early electric vehicles followed very closely the lines laid down and adhered to for so many years by the wagon builder. That is, the entire vehicle was a unit. Then, the practice of making the power-plant and running-gear, or chassis, entirely independent of the body, which obtained in the gasoline field, was followed and is representative of the usual electric vehicle construction today. This permits of fitting any style of body desired by the user. As a matter of fact, as soon as engineering practice became fairly well standardized, as applied to the design of the gasoline-driven car, that of the electric vehicle followed it more or less closely, except as necessarily modified by the difference in the motive power. Thus, it will be noted that the electric has progressed through the stages represented by the angle-iron frame, armored wood frame, and modifications of the two as employed on gasoline cars, to the now generally current type of pressed steel frame. This has the advantage of being extremely strong for its weight. It is composed of side and transverse members produced in hydraulic presses directly from steel plates of about $\frac{5}{16}$-inch thickness, these members being riveted together and further reinforced by gussets at the corners. On account of the height of the vehicle, the frames are made perfectly rectangular and without either a drop or narrowing forward.

The types of suspension employed also show the same variations as are to be found in the gasoline-driven cars, some of the smaller electrics having full elliptic springs as ordinarily employed on wagons, while intermediate and heavy vehicles have either straight semi-elliptic springs front and rear, or a half-platform type of suspension in the rear. A study of the Studebaker and General Vehicle types of delivery wagons and trucks will show how closely they approach to what is considered general practice in the automobile field as a whole. The latest Lansden vehicles are distinguished by a novel form of suspension employing groups of helical springs, and represent about the only departure of note.

Where the axles are concerned, the electric still bears traces of its predecessor, the horse-drawn wagon, as these are usually straight forgings of square section, though tubular axles are employed in some of the lighter cars. The steering spindles on the front axles and the wheel spindles on both front and rear follow conventional practice, as ball or roller bearings are generally employed. Because of the heavy loads carried and the fact that solid tires are used, the entire running gear has to be planned on a very liberal scale. This is likewise true of the springs. While it is desirable that the latter afford as much protection to the mechanism as possible, sufficient stability to carry the load is of more importance than flexibility, as the comparatively slow speeds do not occasion either the rapid oscillations or the violent shocks that are met with in the pleasure car with its light load and high speed.

Motive Power. As already mentioned, the motive power of the majority of smaller electric vehicles consists of a single motor, and in some makes, such as the General Vehicle, this practice is extended into quite heavy units with a corresponding increase in the efficiency of the vehicle as a whole. In order to keep down the weight as well as the space occupied, these motors are very small for their power output and consequently have to be wound for high rotative speeds. They are usually of the series type, of General Electric or Westinghouse make, and are designed to carry heavy overloads for short periods to enable the car to pull out of a bad place, to start with full load on a heavy grade, or to meet similar emergencies, the motor, under such conditions, delivering an amount of power totally disproportionate to its size, and particularly to its normal rating. This brings up a question that has proved very puzzling to the layman, and frequently to the engineer not familiar with electrical practice. If at least 20 to 25 horse-power are necessary for the average small gasoline car, how is it possible to run a delivery wagon with a 2½-horse-power electric motor, and a truck of no mean proportions with but 5 horse-power? The overrating of the amount of power necessary in the first case, and the undervaluation of the actual amount of power available in the second go a long way toward explaining this. Though the gasoline car is equipped with a 25-horse-power motor, it seldom uses more than 40 to 50 per cent of what is available; in fact, assuming the vehicle to be in good condition throughout, it probably does not require more than 10 to 15 horse-power to drive it on the level, at any speed up to 30 miles an hour.

The electric on the other hand, has a 2½-horse-power motor which is really a 10-horse-power motor, or 5 horse-power at least, and which may be 15 horse-power, when occasion demands it, as many of these motors are capable of overloads up to 500 per cent of their normal capacity. Furthermore, there is the extremely important factor of speed and its complement, wind resistance. Speeds are so slow in commercial vehicle practice that wind resistance is practically a negligible factor, even with the towering bodies of motor vans which present a very large area, as this influence does not make itself apparent much under speeds of 25 miles an hour. Discussions which have taken place regarding this seemingly great discrepancy in the motive-power equipment of the average electric and gasoline car, recall those regarding the same feature of the pioneer electric street cars as compared with their predecessors. Two, or three horses at most, sufficed to haul the cars up grades that some of the first power-driven cars with 15-horse-power motors could not get over. In any case, why should it take 15 horse-power to drive a car that had formerly only required a team of horses to move it? Weight and speed were naturally not taken into consideration, as the old horse car was as light as a wagon and ran much easier, though the general misconception prevailing as to just what a horse-power is and what a horse is capable of were principally responsible. Careful experiments carried out by an English engineer have proved conclusively that the average draft horse is capable of exerting the equivalent of all the way from 4 to 13 horse-power for periods as long as five minutes at a time. Consequently, the light car with its two horses really had available several times as much power, based on the horse-power unit, as appeared to be present.

Motor Suspension. Since the employment of spur-gear drives has become less general, the motor is usually suspended from the frame by means of transverse members riveted to the side rails, and is placed near or slightly forward of the center of the chassis, in order to give the best distribution of weight. This is an advantage that is not obtainable when the motors are hung from the rear axle, or too close to it. In view of the high speed at which the motors run—1,800 to 2,000 r. p. m. or more—a reduction in two stages is necessary to avoid the employment of excessively large sprockets. The first step is from the motor to a countershaft by means of a single silent chain of the Morse or Renold type, the motor being suspended in such a manner that it may be moved a short distance one way or the other to permit of adjusting this chain to the proper tension. The large sprocket on the countershaft, which serves to cut down the speed in the proportion of about 1 to 5, also embodies a differential or compensating gear of the usual bevel or spur type, thus making it possible to employ a solid one-piece axle, instead of weakening the latter by inserting the balance gear in it. This is an important feature as the rear axle must bear 60 to 70 per cent of the total weight of both car and load. From the countershaft, chains are run to each of the driving wheels. The relative positions of the countershaft and rear axle are maintained by heavy adjustable radius rods, attached forward to the outer ends of the countershaft, and at the rear to the axle. These take the stress of the drive off the springs and counteract the tendency of the chains to draw the rear axle toward the countershaft under the pull of the motor.

Where two motors are employed, as in the Studebaker 2,000-pound wagons, they are suspended side by side from the frame by special swinging hangers with their armatures practically in line with one another. But each motor is entirely independent of the other and serves to drive one of the rear wheels to which it is directly connected by means of a roller chain, passing over a small sprocket on the armature shaft of the motor forward and a large one on the hub of the driving wheel at the rear, there being but a single step in the speed reduction in this case. As there is no mechanical connection between the two motors, or between the two driven wheels, the latter are free to rotate at different speeds when necessary and a compensating gear is dispensed with altogether. This also gives the further advantage of not losing traction entirely when one of the driving wheels turns loosely on ice, mud or sand, as is the case with the differential, which nullifies the driving effort applied to the opposite wheel when its mate revolves freely. Chain drive as now employed is not only more efficient, but less noisy and much easier to maintain and repair than the spur-gear drive formerly in vogue, though the protection of the chains by suitable cases to keep off mud and maintain lubrication would be an improvement.

As the motors commonly employed are wound to take current at 80 to 85 volts, the battery consists of 44 cells, divided into three or four groups of cells held in separate oak boxes, or *trays* as they are termed, to facilitate handling. This voltage is standard, regardless of the size of the vehicle, the latter being compensated for by changing the capacity of the battery. Thus, for very small delivery wagons, the cells each contain three positive and four negative plates of medium size giving an 85-ampere-hour discharge capacity, while a 1,000-pound wagon is equipped with a battery having nine-plate cells with a capacity of 112 ampere hours; a 2,000-pound wagon, eleven-plate cells of larger dimensions, giving 140 ampere hours; and so on in accordance with the size of the vehicle and the load it is designed to carry. However, the weight of the battery increases so rapidly with increase in capacity that it has not been found desirable to attempt to use very large units.

In the very small delivery wagons listed some years ago, it was customary to carry the battery on the floor of the vehicle, putting a second flooring above it to accommodate the load. This practice has been abandoned for obvious reasons, as it made both the loading floor and the center of gravity of the vehicle much too high. Practically all electric vehicles at the present time have the battery underslung, *i. e.*, carried in a cradle supported from the frame of the chassis. This cradle is enclosed as a battery box for protection against mud and water, and has hinged doors at the ends through which the battery may be introduced or removed. By this arrangement the weight of the battery, which is the heaviest single item in the entire construction, is distributed evenly between the forward and rear wheels and leaves the entire floor space of the wagon available for the load. All of the wiring between the battery, controller, and motor is carried beneath the floor and is protected from injury.

Control. The controller itself is placed either beneath the seat or under the footboards in the case of delivery wagons and light trucks, and is similar in construction to those employed on street cars, but of much smaller size due to the low voltage and comparatively small amount of current to be handled. It is operated by a small hand lever and provides three to five speeds ahead and two or three reverse, all of which are obtainable by moving the same lever, although a special lock or catch must first be operated before the vehicle can be moved backward. This usually takes the form of a pedal or kick plate which may be depressed with the heel and frequently must be held down while reversing. It automatically returns the controller to the ahead position when released, in order to prevent the vehicle from being backed inadvertently.

At first, arrangements for steering took the form adopted on the earliest gasoline cars, that is, the tiller or hand-lever form, but, owing to its numerous shortcomings, this has now disappeared on all but the lightest wagons. Left-hand control is often provided, *i. e.*, both the controlling lever and the steering wheel are placed on the left side of the wagon, which is most convenient on delivery wagons as the driver's helper may leave and enter the wagon without going round the vehicle.

Wheels. The usual artillery pattern, wood wheels are employed and are almost universally carried on ball or roller bearings. Their sizes reveal the conflict between the influence of ordinary delivery wagon design and automobile practice, as some have 36-inch front and 42-inch rear wheels—an old time horse-drawn wagon standard—while others have 32- or 34-inch wheels all round as has become customary in automobile building. The larger wheels are advantageous, however, as they run easier on poor pavements and consume slightly less power, their greater diameter being compensated for by a correspondingly greater drop in the speed reduction from the motor to the rear wheels, in order to keep the speed of the vehicle the same. By modifying the design of the axles or frame, or both, the loading platform of the wagon may be kept at the same height relative to the ground, regardless of the size of the wheels, so that the employment of larger diameters is becoming, more common. This, again, is but a reflection of the tendency of design in gasoline pleasure car construction, in which 42-inch wheels are now employed, and affords an instance of reversion to original standards, as pioneer automobiles were all of the high-wheel type.

Brakes. Owing to the comparatively low speeds, the braking equipment usually consists of but a single set of drums attached to the driving wheels. Against the inner faces of these, bronze shoes are expanded directly on the steel face of the drum by means of a pedal and the usual brake rigging beneath the car. As is the case in practically all chain-driven cars, the braking drums carry the driving sprockets on their outer faces. In case of emergency, the vehicle may be brought to a sudden stop by reversing the motor, although this subjects the motor as well as the entire vehicle to unusually severe stresses.

Tires. While solid rubber tires are most generally employed, this is not necessarily so, as where the merchandise to be carried is of a light or fragile nature, or where speed is to be one of the chief features of the delivery service, pneumatic tires are preferable. They not only reduce the liability to breakage, but also lessen the cost of maintaining the vehicle in repair. However, as there are comparatively few branches of commercial service in which the pneumatic tire is economically practical, its use is very limited. The solid tires employed vary in size from two to four inches, and for weights in excess of the capacity of the latter, they are used in twin form on the rear wheels.

Types. Fig. 1 illustrates the Studebaker 800-pound load capacity, delivery wagon. It is equipped with a 40-cell Exide lead-plate battery, supplying current at 84 volts to two high-speed series motors which drive the rear wheels directly by chains, as already described. The vehicle has a speed of 2 miles to 12 miles per hour, and is capable of traveling 35 miles on a single charge of the battery. The battery is located almost directly under the center of the pressed steel frame, and the battery compartment is built integral with the frame itself, forming an inverted truss. The axles are heavy drop-forgings, and owing to the use of two motors, no differential is employed on the rear, the motors, battery, and all other parts of the mechanism being carried by the springs, which, in the smaller types, are of the elliptic type ordinarily employed in wagon-building practice. There are two sets of brakes, each working independently, and arranged to be applied by pedal levers, one set controlling expanding bands in drums on the rear wheel hubs, while the other brakes are of the same type but are mounted on the motor countershafts. Plain parallel bearings are employed with ample bearing surface. The dimensions of the 800-pound wagon are: wheel base, 84 inches; gauge, 59 inches; wheels, 36 by 2½ inches front and 42 by 2½ inches rear, the tire equipment being solid rubber, though iron or wood tires may also be had.

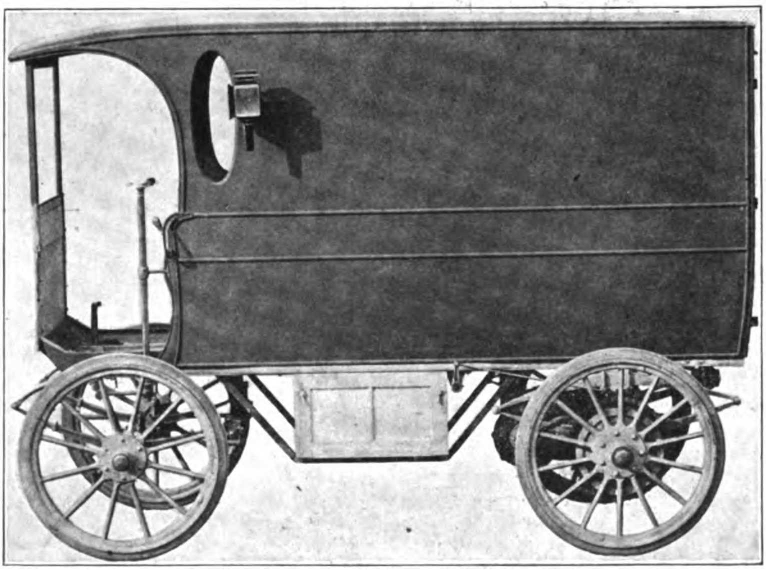


Fig. 1. Studebaker 800-Pound Electric Delivery Wagon.

In addition to the usual control, an emergency switch is provided within convenient reach of the driver, making it possible to quickly shut off the power from the motors altogether. This switch can only be moved when in a certain position; it also answers as a lock when the vehicle is standing. One of the 1,500-pound Studebaker wagons is shown in Fig. 2 with an open express type of body, and it will be noted that its design is identical with the smaller vehicle already described.

The Waverley electric delivery wagons are characterized by the employment of a single motor, as is also the case with the majority of others in this field. This drives to a countershaft, from which the final drive is taken to the rear wheels by the usual roller chains and sprockets. They are equipped with 42 cells of Exide lead-plate battery, or of the National battery. The dimensions of the 1,200-pound delivery wagon are: 91-inch wheel base, 60-inch tread, with 32-inch front and 36-inch rear wheels, equipped with 3-inch solid rubber tires. The suspension takes the form of semi-elliptic springs in the front and full elliptic in the rear, the brakes being of the conventional internal expanding type in drums on the rear hubs, sup-

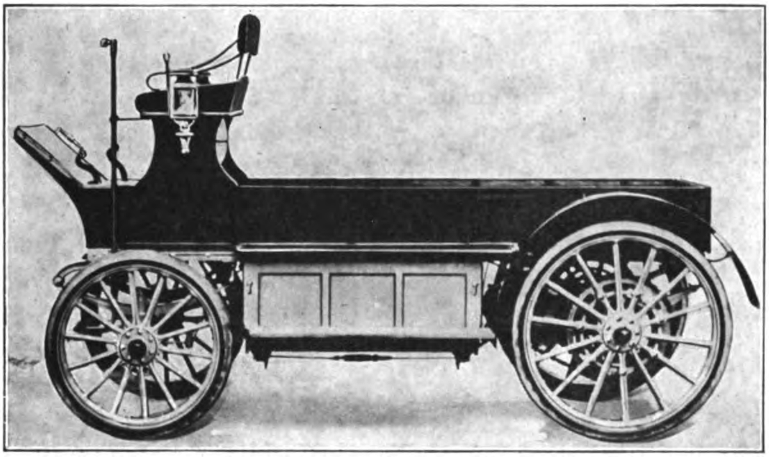


Fig. 2. Studebaker 1500-Pound Convertible Station Wagon.

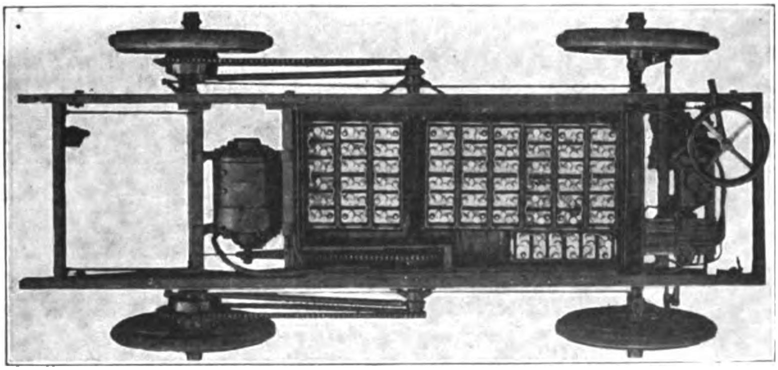


Fig. 3. Lansden Delivery Chassis.

plemented by a countershaft brake. The axles are plain drop-forgings, the differential being placed in the countershaft. Steering is by wheel, which controls a gear of the pinion and sector type.

The Lansden delivery wagons represent a departure from the conventional type in several respects. In the first place, they employ a 60-cell Edison battery, instead of the usual lead-plate type. Though considerably lighter, this cell has a much lower voltage than the lead cell, which accounts for the greater number employed and the extra space required on the vehicle as shown by the chassis plan view of a Lansden, Fig. 3. It will also be noted from this that a single motor is employed, wound to take current at 72 volts. It is located at the rear of the chassis and drives forward by means of a single chain to a countershaft. The latter, instead of being of the round or square section ordinarily employed, takes the form of a flat bar 2 inches wide by $\frac{3}{8}$ to $\frac{1}{4}$ inch thick, according to the power it is to transmit. The material is spring steel, so that the countershaft acts as a cushion to prevent the stresses of starting from being transmitted to the tires and the mechanism of the car, and it has proved unusually effective for this purpose. From this countershaft, the final drive is taken to the rear wheels by long side chains of the usual roller type. The countershaft also embodies the differential, so that the axles are plain, the wheels being carried on long bronze sleeve bearings. The steering wheel is placed on the left-hand side and the steering column carries the controller lever. The brakes in the rear hubs are operated by a pedal. The appearance of a complete delivery wagon of the Lansden type may be judged from Fig. 4.

The load capacity of this wagon is 1,500 pounds and it has a radius of 40 miles on a single charge of the battery at an average speed of 11 miles an hour. The weight of the complete vehicle is 3,000 pounds, its wheel base is 88 inches, its tread 56 inches, and the tire equipment consists of 32-inch by 3-inch solid rubber tires all round. The vehicle is operated by means of a special form of continuous torque controller, giving three or four speeds forward, as desired by the purchaser, and two speeds on reverse.

Range of Usefulness of the Electric Delivery Wagon. It has been regarded as a generally accepted fact in the past that the usefulness of the electric delivery wagon must, of necessity, be limited to strictly city service, where the routes are well paved and the run does not

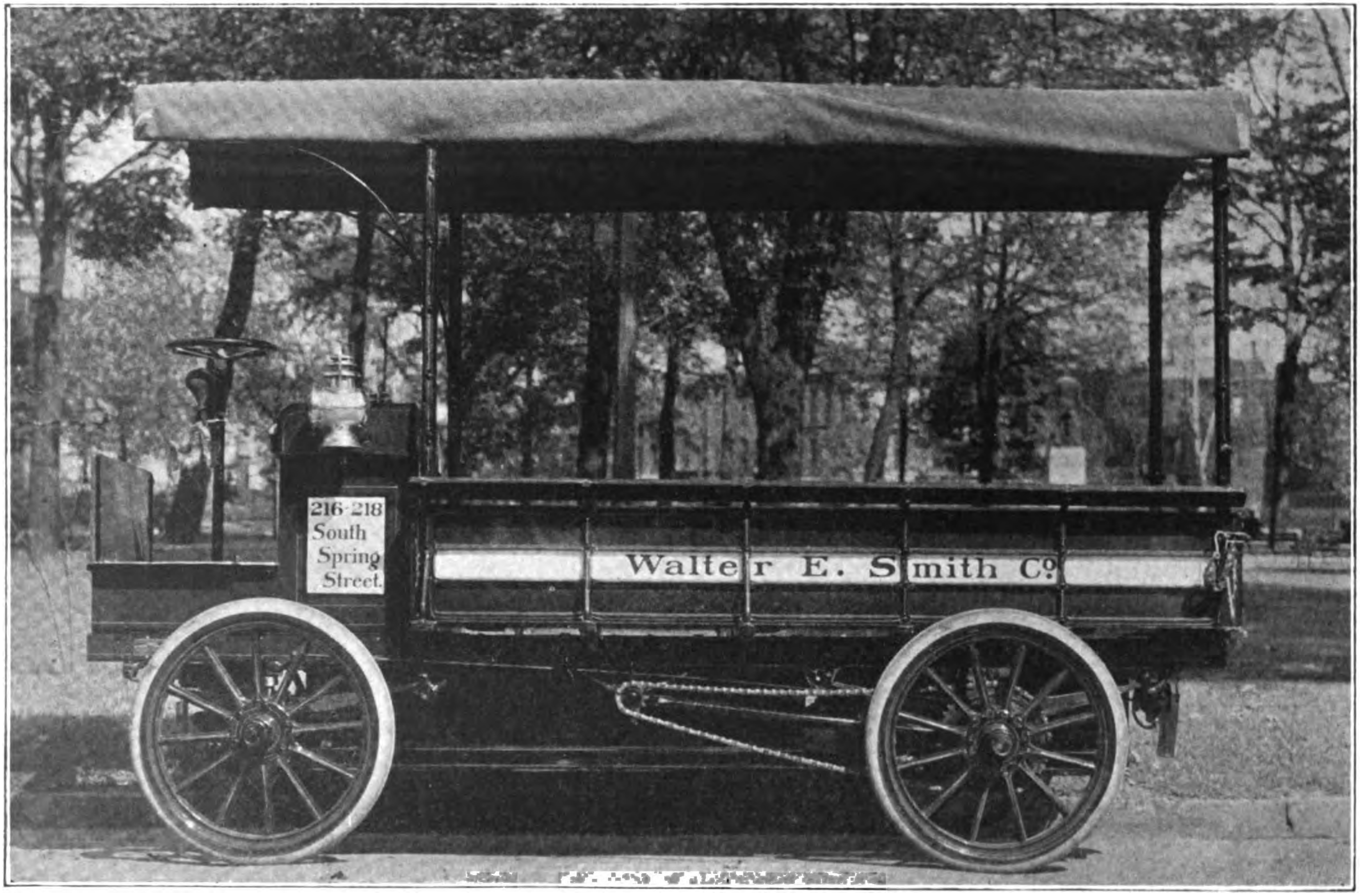


Fig. 4. Lansden Electric Delivery Wagon.

involve traveling more than 30 to 35 miles a day at the most—at least, without affording an opportunity for a stop during the lunch hour in order to give the batteries a "boost," at some convenient charging station. This was quite true in earlier days and the distances were even shorter for a day's work, but considerable improvement has been made both in the vehicles generally and the batteries since then. As a result, it has become possible to employ electric delivery wagons to great advantage in suburban service, and what would have been considered remarkable records not long ago are now matters of course.

For example, a 1,000-pound Lansden delivery wagon—equipped with one of the new Edison nickel-iron batteries of 65 cells, weighing 700 pounds—operating constantly in the service of one of New York's largest drygoods houses, which regularly maintains 41 electric and gasoline machines in addition to 100 head of horses, covered 45 miles over heavy, muddy roads and made 175 stops for package deliveries on the trip to Coney Island and return. The same wagon was later transferred to a route on the Jersey side of the Hudson River, extending down the Bergen Point peninsula to Bayonne, and regularly served a route of 43 miles, calling for an average of 125 daily deliveries, without requiring any "boosting" of the battery.

In the service of the same house, a Lansden 2,000-pound capacity wagon, weighing 2,460 pounds, and equipped with a new Edison battery, weighing 1,200 pounds, ran 93 miles on three consecutive days, making an average of 100 stops per day, on a single charge of the battery. The first two days' run were to Bergen Point, and the third to Staten Island, where the roads are very hilly, though generally of good macadam construction. The same wagon and battery, operating in the service of the Macy department store in May, 1909, made a trip to Morristown and return, covering 72 miles over hilly roads and making 45 deliveries, on a single charge. On another occasion, it was sent to Tottenville, Staten Island, over equally hilly roads, making 60 stops and covering 56 miles on one charge. In regular daily service, this wagon makes 56 to 57 miles a day on an average without any necessity for boosting the battery, returning to the garage at night good for 10 to 12 miles more. Its working time has averaged 14 to 18 hours a day, being recharged during the night at a 40-ampere rate for six or seven hours.

The delivery experts of the two establishments in question are of the opinion that this wagon is easily capable of covering the longest and hardest routes operated out of New York City by any company, and that the capacity of the wagon is far in excess of the endurance of the driver and helper. It must be admitted that these are exceptional records for electric vehicles and surpass the capabilities of the heavier types propelled by lead storage batteries, but they are sufficient to demonstrate that the electric is not a strictly city-service machine and likewise that as a class, the electrically-driven vehicle is not the decadent type that many suppose it to be.

ELECTRIC TRUCKS

In the classification of vehicles as listed by some manufacturers there is more or less difficulty in drawing a distinct line between the delivery wagon and the truck, as a 2,000-pound delivery wagon chassis when fitted with what is known as a *stake body*—that is, an open platform with removable stakes for holding on the load—is frequently listed as a "light truck." It is the same chassis as that on which the delivery wagon body is mounted, and is simply fitted for transporting a different character of merchandise, usually goods in cases or in bulk. Between the light truck and the heavier vehicle intended for the same general service, the chief difference is that of dimension, even up to the 10,000-pound, or 5-ton truck, which is about the maximum that has been found practicable for electric propulsion.

There is little, if any, difference in design, the frames, axles, wheels, springs, and transmission simply being made heavier in proportion to the great increase in load to be carried, while there is a corresponding difference in the power of the motor or motors and in the size of the chains or other essentials of the transmission. As already mentioned, some makers, such as the General Vehicle, adhere to the single motor power plant even in sizes up to 2-ton and 3-ton capacity, on the score of increased economy and higher efficiency, while others, such as the Studebaker, employ two motors on vehicles as small as the 2,000-pound size.

The dividing line between the capabilities of the electric and gasoline vehicle for the transportation of heavy merchandise, in large quantities, is more sharply drawn than where lighter types of the two are concerned. It has been demonstrated that the electric delivery wagon is capable of performing more work in the course of a day than lies within the capacity of the driver, while its average speed is quite up to that usually permitted by legal restriction in urban and outlying communities. It has the advantages already pointed out of being handled by an unskilled driver and is not subject to the latter's lack of knowledge to the same extent as is the gasoline-driven car, the adjustments of which may be easily tinkered with and are not difficult to derange, so that it appears quite probable that both types will continue as active competitors in this particular field.

Power Limits. The matter assumes a totally different aspect as weights increase, owing to an inherent shortcoming of the electric vehicle, viz, lack of power capacity. The amount of energy that can be chemically converted and held in reserve by the battery for use in the motors has very sharply defined limits. Weight of the battery itself is naturally the principal factor that determines this, and, beyond a certain point, its increase is totally disproportionate to the gain in capacity. As this has a direct bearing on the load efficiency of the vehicle itself, *i. e.*, the amount of useful load it can transport as compared with its own weight, there is a still further limitation. This will serve to explain why it has not been found practical to build electric vehicles with a capacity exceeding five tons. It may be added here, that a comparatively small number of the latter has ever been put in service, and as an electric vehicle of this size forms such a close approach to what experience has demonstrated to be the available limit of usefulness for this method of propulsion, that its use is seldom considered favorably by transportation experts.

Next to the delivery wagon, in which electric power has scored its greatest success, trucks of 2-ton and 3-ton capacity are the most common forms of electric vehicles. In order to obtain the increase in load-carrying capacity, the size of the motor must naturally be enlarged with a corresponding increase in the power consumption, which calls for a very much larger battery. In order that the capacity of the latter may be sufficient to give the vehicle a practical radius of travel on a single charge, without unduly adding to the weight, the speed is reduced, and electric trucks of 2-ton capacity usually have an average speed of 8 to 10 miles an hour; 3-ton trucks, 6 to 9 miles an hour, and 5-ton trucks seldom exceed 6 miles an hour. Even at these low speeds, it is difficult to obtain a daily mileage exceeding 20 to 25 miles on a single charge of the battery, and where the latter is of the lead-plate type and has been allowed to fall off in efficiency through deterioration or careless handling, they will not accomplish that distance on a single charge, without resorting to "boosting" the battery. This means giving the battery a heavy charge, *i. e.*, sending current into it at a high charging rate for a short period before it is more than three-quarters discharged, in order to enable the vehicle to return to its garage. As will be noted in the chapter on the subject of charging the batteries, this is poor practice and is detrimental to the battery. A route should not be served by an electric vehicle whose capacity is not sufficient to cover the distance without resorting to boosting.

Some examples taken from actual practice will best serve to illustrate the foregoing. For example, take the Studebaker baggage transfer wagon, Fig. 5. This is rated as having a useful load capacity of 2,500 pounds. According to the makers, this is a "teamster's rating" and the wagon is designed to give good service with frequent overloads ranging as high as 100 per cent, on the assumption that the average load, year in and year out, will not exceed 2,500 pounds. It must naturally be borne in mind, however, that the speed and traveling radius are limited entirely by the load carried. For instance, this wagon has a speed of 9½ miles an hour on good, hard, level roads, with an average load of two-thirds its rated capacity. It will be noted that this machine properly falls within the light truck class and the manufacturers offer it either in the form illustrated, or with a delivery body. Its construction is along conventional lines, employing a pressed steel frame, semi-elliptic springs, and drive by two motors with a single-speed reduction by chains to the 42-inch driving wheels, in accordance with the usual Studebaker practice. The front wheels are 36 inches in diameter, the wheel base is 104 inches, and the battery complete is suspended from the frame in a substantial battery box, hung just forward of the motors. Doors at the side permit the withdrawal of the battery in trays as usual. The dimensions of the load-carrying space are 115 inches in length by 43 inches in width for the open wagon, and 63 inches in height, when a delivery body is employed.

Next to the type just described is the Studebaker 4,000-pound

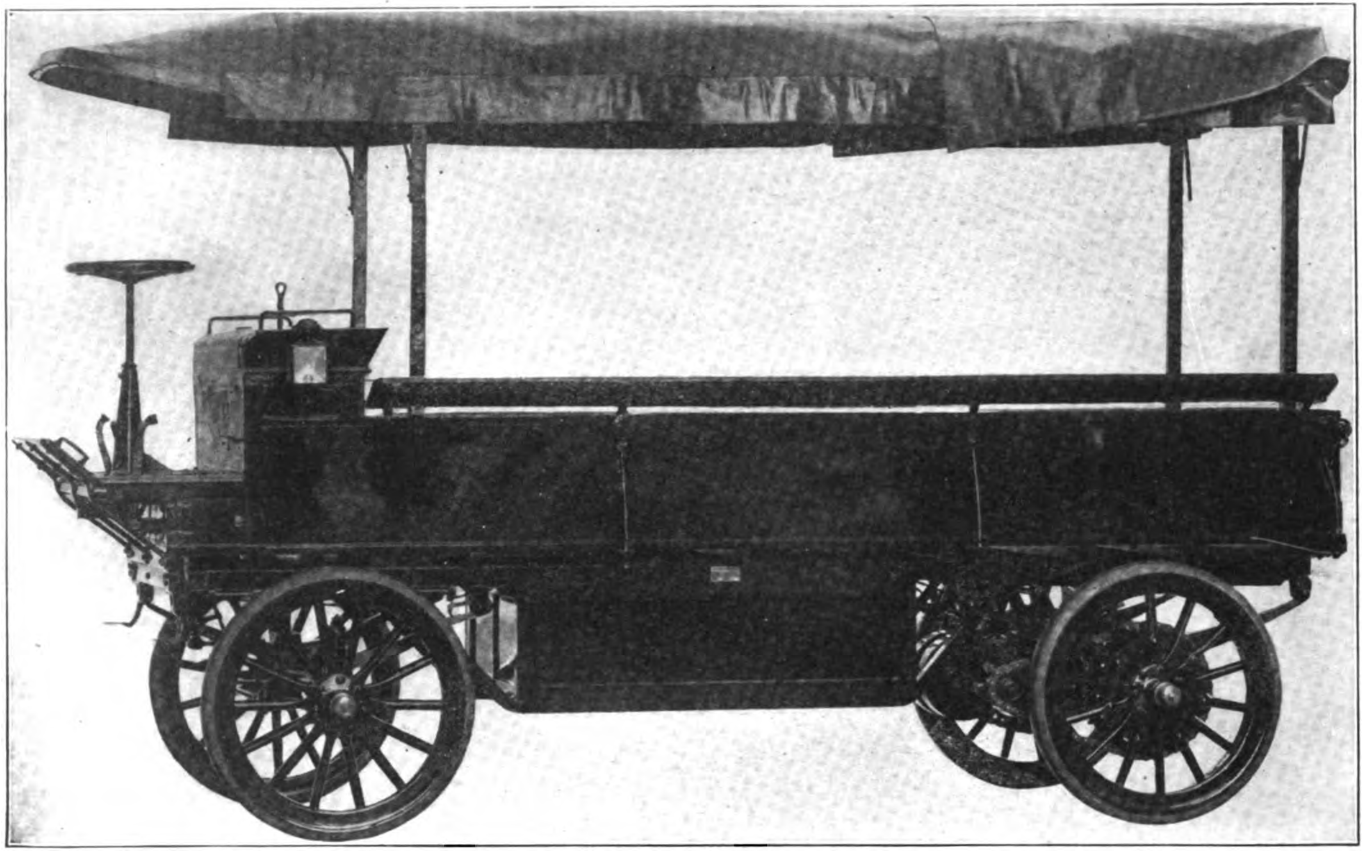


Fig. 5. Studebaker 2,500-Pound Express Wagon.

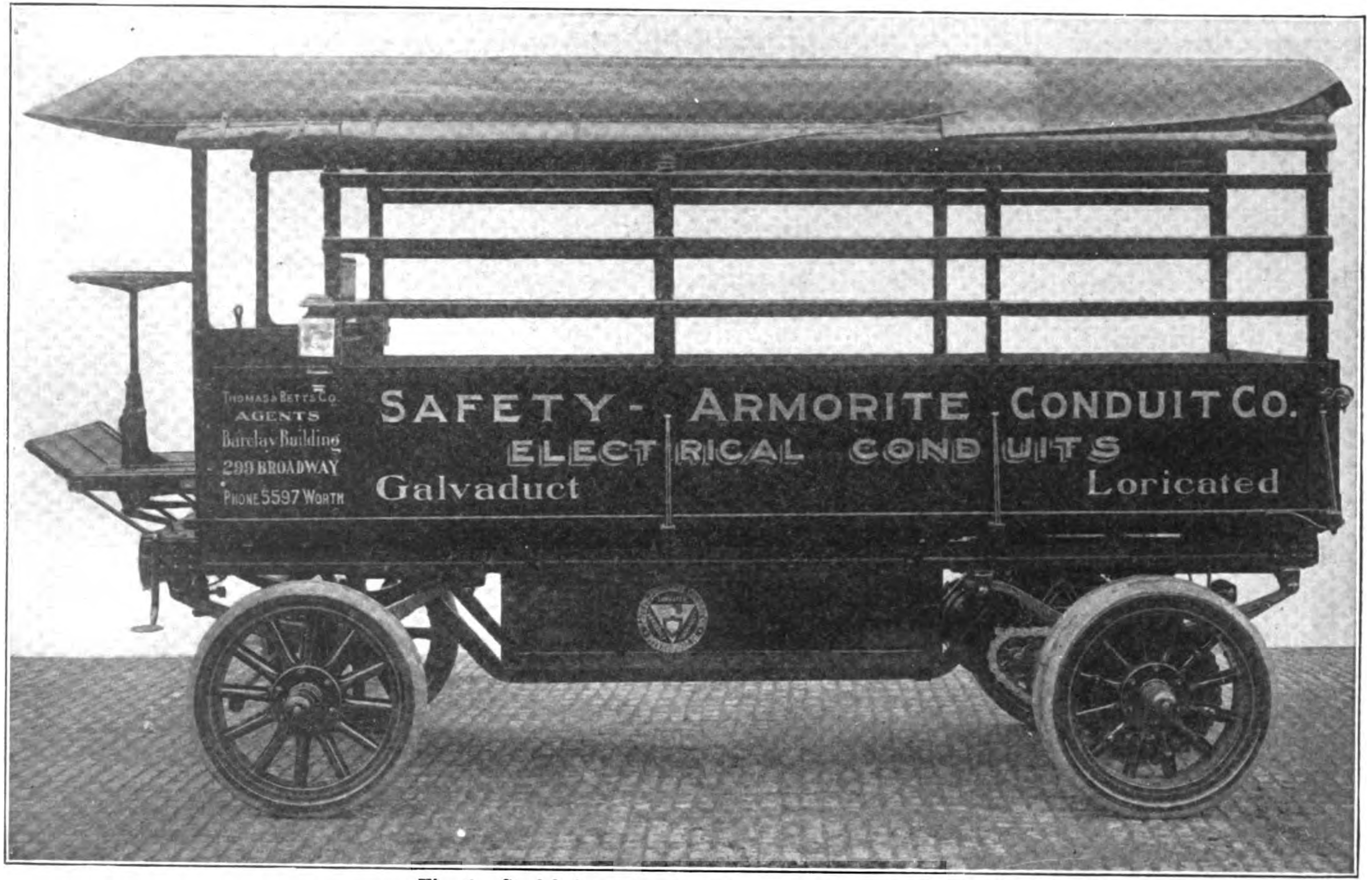


Fig. 6. Studebaker 7,000-Pound Special Electric Wagon.

stake truck. This is also a teamster's rating and the vehicle is capable of frequent overloads not exceeding 50 per cent of its normal capacity, under conditions similar to those already referred to in the case of the lighter vehicle. Its speed with two-thirds of its rated capacity on level, hard roads, is the same as before, *i. e.*, 9¼ miles an hour. It has a wheel base of 117 inches, gauge of 62½ inches, and is fitted with 36-inch artillery wheels, front and rear, the tires on the rear being of the twin type, measuring 3½ inches in diameter, while the forward ones are 5-inch single, solid rubber tires. The dimensions of its load-carrying space are 156 inches long by 49½ inches wide.

So far as their appearance is concerned, the Studebaker 7,000 and 10,000-pound electric wagons, do not differ materially from the 2-ton size. Their speeds are respectively 9 miles and 7½ miles an hour, these being the maximum with two-thirds capacity, as before, the average rate of travel naturally being less. The wheel base is 127 inches in the smaller, and 126 inches in the larger, with gauges of 75 inches and 76 inches respectively; 36-inch wheels are employed throughout on the running gear; the only difference being in the size of the tires, which are 4-inch twin type on the rear in both cases, with 5-inch single forward on the smaller, and 7-inch on the larger truck. The load platform dimensions of the 3½-ton truck are 157 by 56 inches and for the larger, 169¼ by 58½ inches. A Studebaker 7,000-pound wagon is shown, in Fig. 6, while the 5-ton wagon of the same make is shown in Fig. 7. One of the latter is

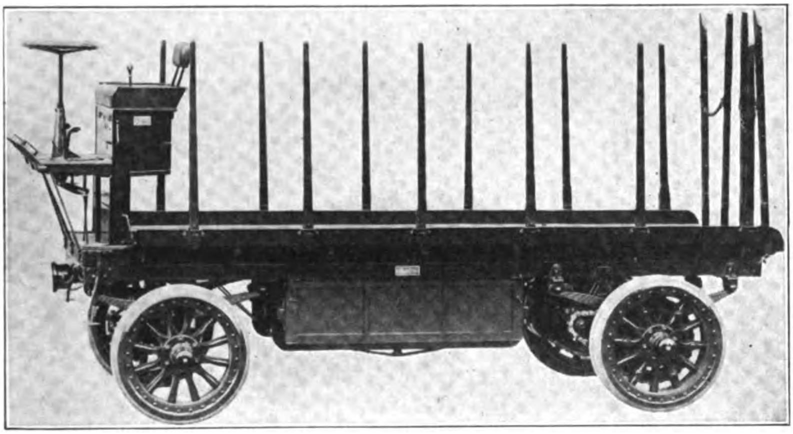


Fig. 7. Studebaker 10,000-Pound Stake Truck.

employed by the U. S. Government in connection with the Marine Arsenal at Washington, D. C., and renders excellent service in the transportation of heavy forgings and other gun parts.

Service. Some idea of the service rendered by an electric vehicle in strictly city use may be gained from the work accomplished by a Studebaker 1,500-pound delivery wagon of the type shown in Fig. 8. This wagon was in service steadily for 15 months and was never idle except when the batteries were being washed. It was kept running seven days a week, and frequently at night in addition, and during that time averaged 24 miles a day. One of the 2,500-pound size averaged 32 to 35 miles a day on a single charge of the battery, making a total of 1,000 miles a month of city travel for four months' running. This car was also fitted with a delivery wagon body of the usual enclosed type. One of the numerous styles of bodies available is shown in Fig. 9, which is a small sight-seeing 'bus mounted on a 1,500-pound capacity chassis.

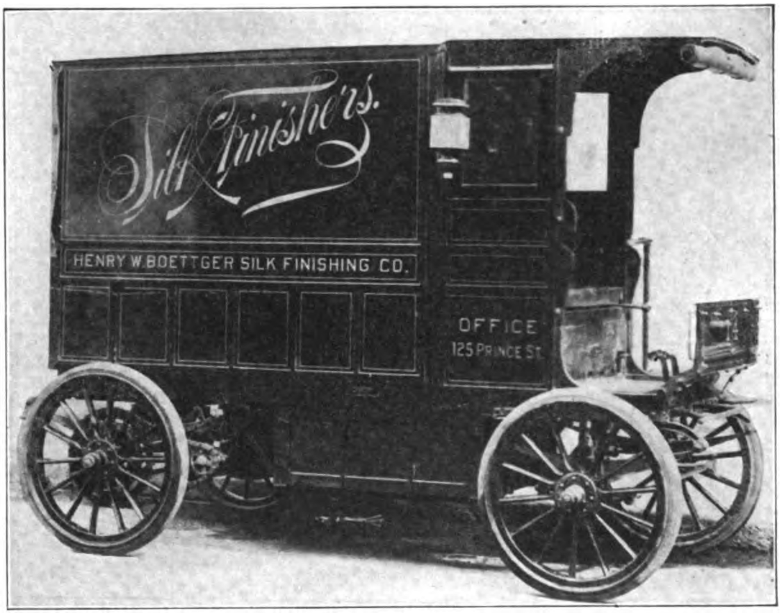


Fig. 8. Studebaker 1,500-Pound Delivery Wagon.

Heavy Types. As further examples of the heavier types of electric trucks, there may be cited the Waverly two- and three-ton sizes. These trucks are fitted with a battery of 42 Exide cells having large plates and are equipped with a G. E. motor driving the rear wheels through the medium of one gear reduction, through herringbone pinion and gear, and a first speed reduction through a chain. In other respects, their construction is substantially the same as in the case of the vehicles just described. The 2-ton Waverly truck has a 111-inch wheel base with 73-inch gauge, while the 3-ton size measures 118 inches on the wheel base, the tread being the same. Both bodies have been designed for merchandise of an intermediate character, where weight is concerned,

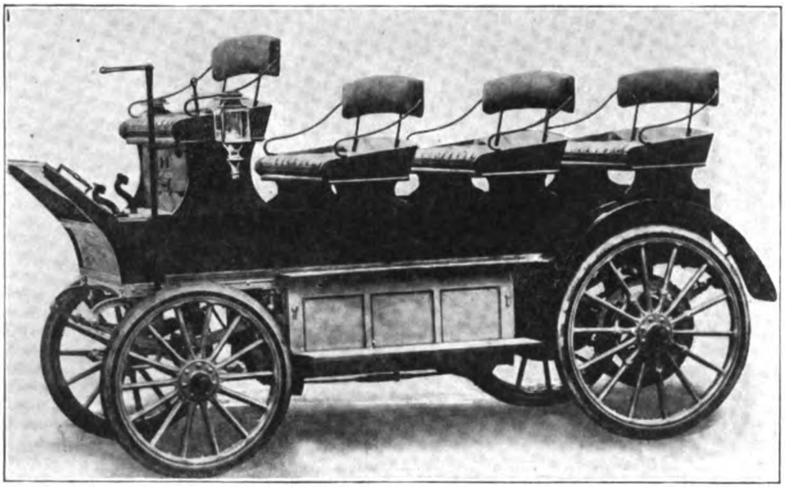


Fig. 9. Studebaker 1,500-Pound Convertible Station Wagon.

and the load space is accordingly very large, being 192 inches by 72 inches by 84 inches high, in the 2-ton, and 156 inches by 54 inches by 72 inches high in the larger. Trucks of this make are distinguished by a silent chain drive from the motor to a short countershaft, constituting the first speed reduction The motor itself is placed closer to the rear axle than is customary in most other types and the silent chain is very short. This countershaft is equipped with a universal joint close to each end, while at each extremity it carries a pinion meshing with a gear on the axle itself. The gearing is very silent and efficient and is of the herringbone type in which the teeth are of widened V form.

The electrics listed by the General Vehicle Company afford an excellent example of a standard design of chassis applied to cars ranging from 1,000 pounds capacity up to 5 tons, the intermediate sizes being 2,000 pounds, 2 tons, and 3½ tons. The first two are naturally delivery wagons and are capable of traveling 45 miles on a single charge of the battery at a maximum speed of 11 and 10 miles per hour respectively. The 2-ton wagon, while capable of the same mileage, has a maximum speed of but 9 miles per hour. This is further reduced to 8 miles an hour for the 3½-ton truck, which has a radius of but 40 miles on a charge, while the 5-ton truck travels but 7 miles an hour as a maximum and has an extreme radius of but 35 miles on a charge. In every case, but a single motor is used, and as the design in all other respects is also standard for all sizes, a description of the 2,000-pound wagon will suffice.

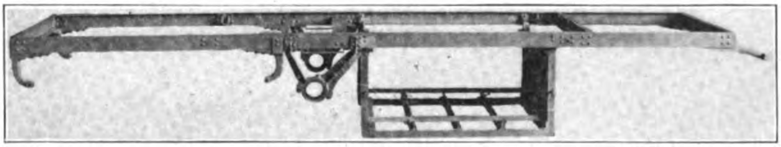


Fig. 10. General Vehicle Company Pressed Steel Frame.

With the exception of the use of a single-motor drive, a large number of the parts employed are practically the same as those used in other makes of electrics. The foundation of the entire car consists of a pressed steel frame, Fig. 10, to which is directly riveted the cradle for carrying the battery, the spring hangers, and the supports for the countershaft bearings. The view of the complete chassis given in Fig. 11, is taken from below and illustrates every essential except the battery. From left to right there are the semi-elliptic rear springs, the solid steel rear axle, artillery wheels with solid rubber tires and large driven sprockets, driving chains, the single motor suspended directly from the frame, the silent chain drive from the motor to the countershaft, the terminal board for the wiring from the controller to the motor, and the countershaft with its radius rods to equalize and maintain its distance from the rear axle. These rods also serve to take the stresses of driving off the rear springs. Just in front of the countershaft is the steel cradle for the battery trays, then at

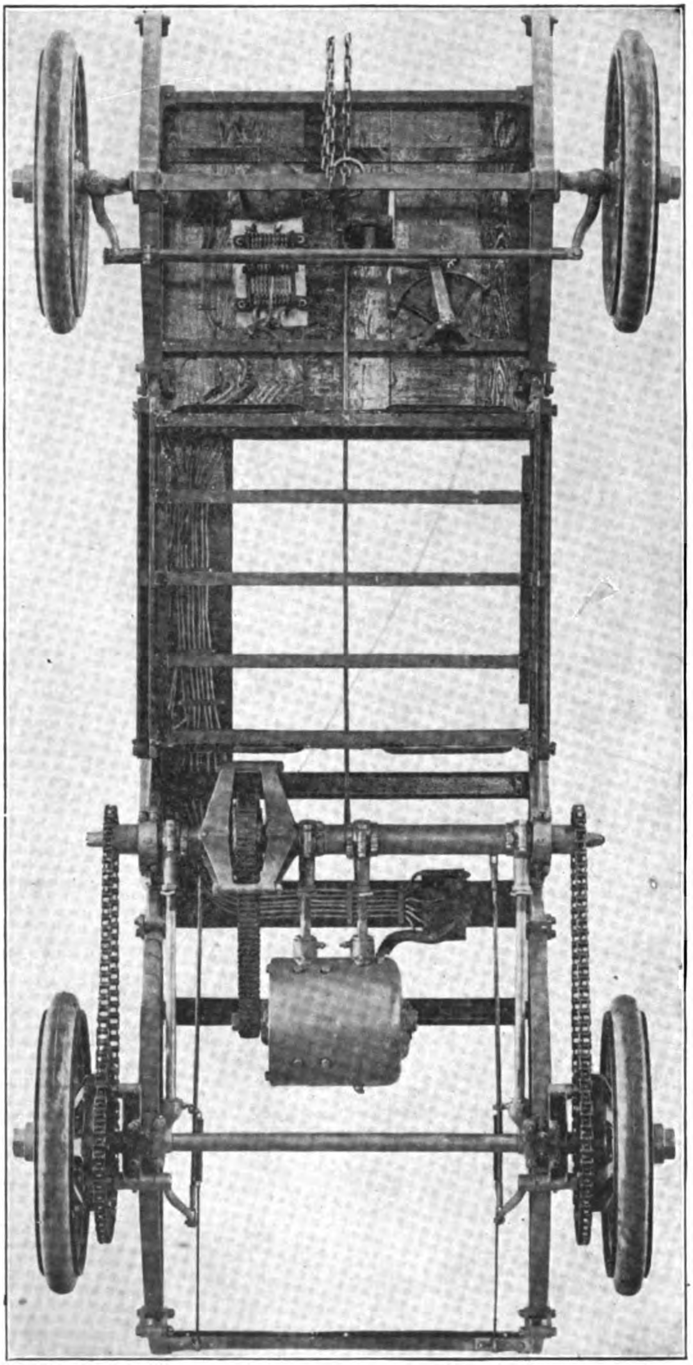


Fig. 11. General Vehicle Complete Chassis—Taken from Below.

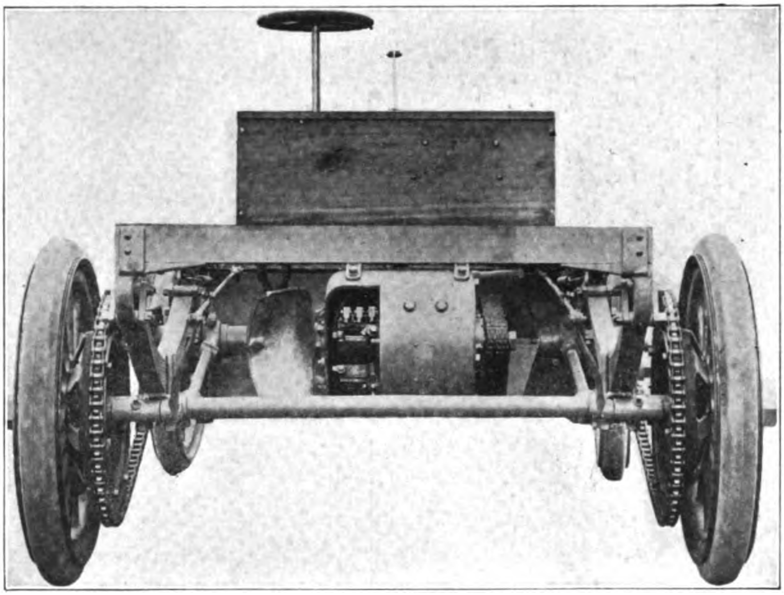


Fig. 12. General Vehicle Company Chassis—Rear View.

the lower side the steering gear, and at the upper a resistance, and the bell, the forward axle, springs, wheels, and so forth.

An excellent view of the entire rear construction which gives a

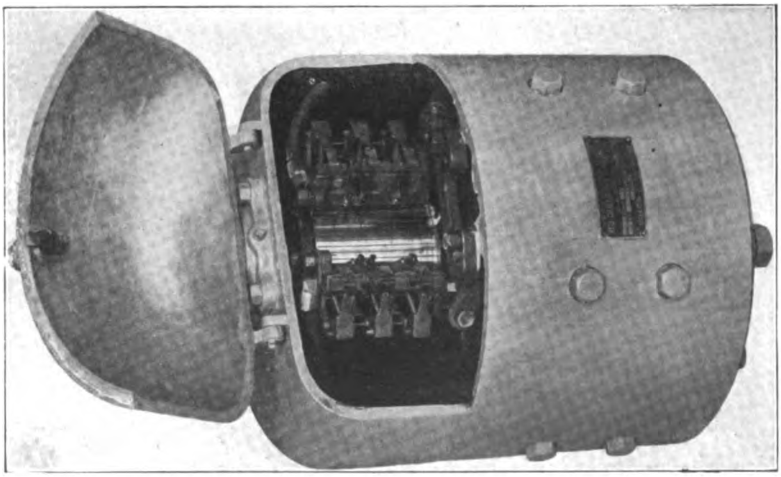


Fig. 13. General Electric Motor.

clear idea of the arrangement of the power and the drive, is shown in Fig. 12, while the essentials comprising it are shown in detail in Fig. 13—which is the G. E. multipolar, ironclad motor—Fig. 14—the countershaft with its supporting housing—and Fig. 15—the same part, showing the differential driving shafts and sprockets as well as the two types of chains employed. Fig. 16 shows the rear axle, and Fig. 17, one of the rear wheels with its attached sprocket, while the forward axle and its steering attachments is shown in Fig. 18. The type of controller employed, together with its operating lever, is shown in Fig. 19, while Fig. 20 illustrates the usual charging plug connection used on commercial electric vehicles.

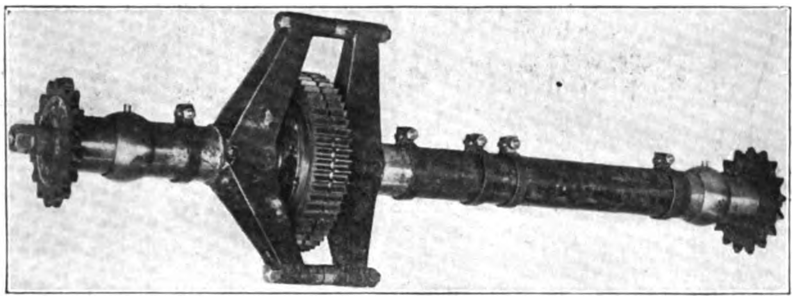


Fig. 14. General Vehicle Company Countershaft and Housing.

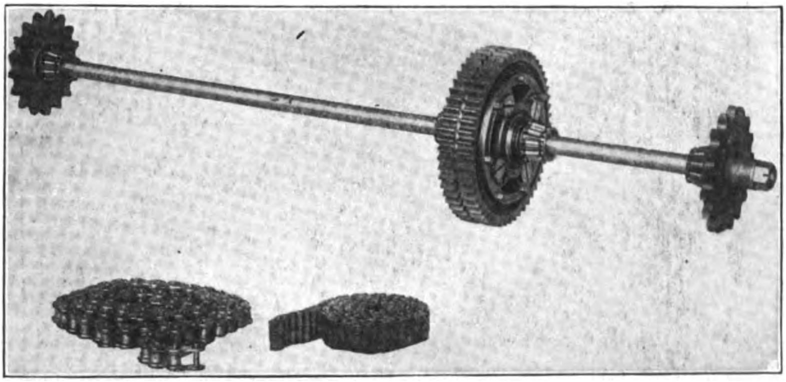


Fig. 15. Countershaft without Housing Showing Differential Gears and Chains.

Battery Specifications. A 44-cell storage battery furnishes current at 85 volts, the motor being wound to operate economically at this voltage. The battery is in sectional form in crates of such

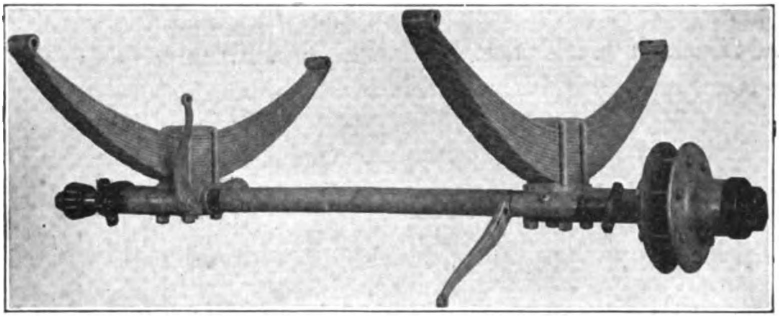


Fig. 16. General Vehicle Company Rear Axle.

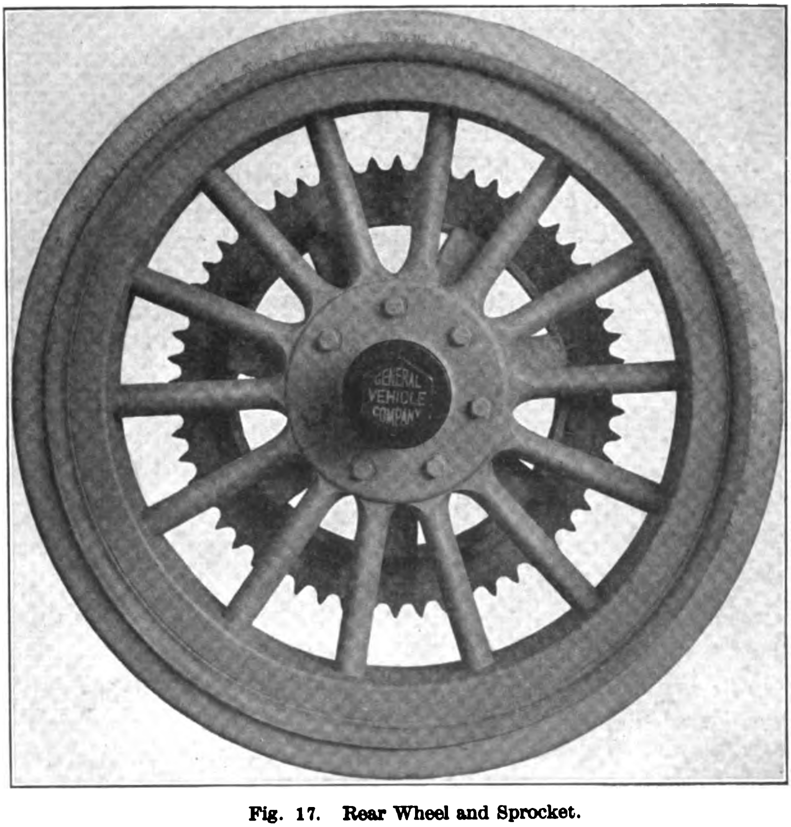


Fig. 17. Rear Wheel and Sprocket.

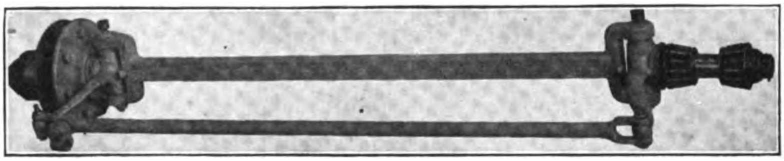


Fig. 18. General Vehicle Company Front Axle.

weight and size as to permit of easy removal or replacement from either side of the vehicle. It is so arranged that it may be recharged without disturbing it, but where two batteries are employed, a charged set may be easily and quickly substituted for the exhausted battery.

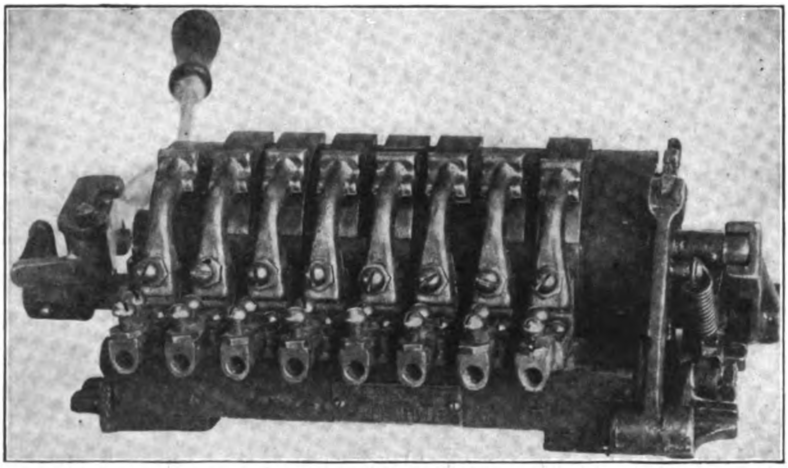


Fig. 19. General Vehicle Controller.

The controller is of the continuous torque type, which permits of changing the motor speeds by degrees without interrupting the power between any of the steps. This gives a gradual and steady acceleration,

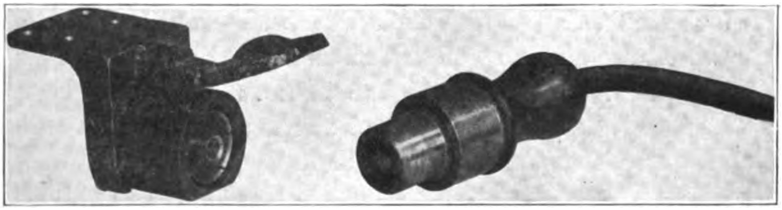


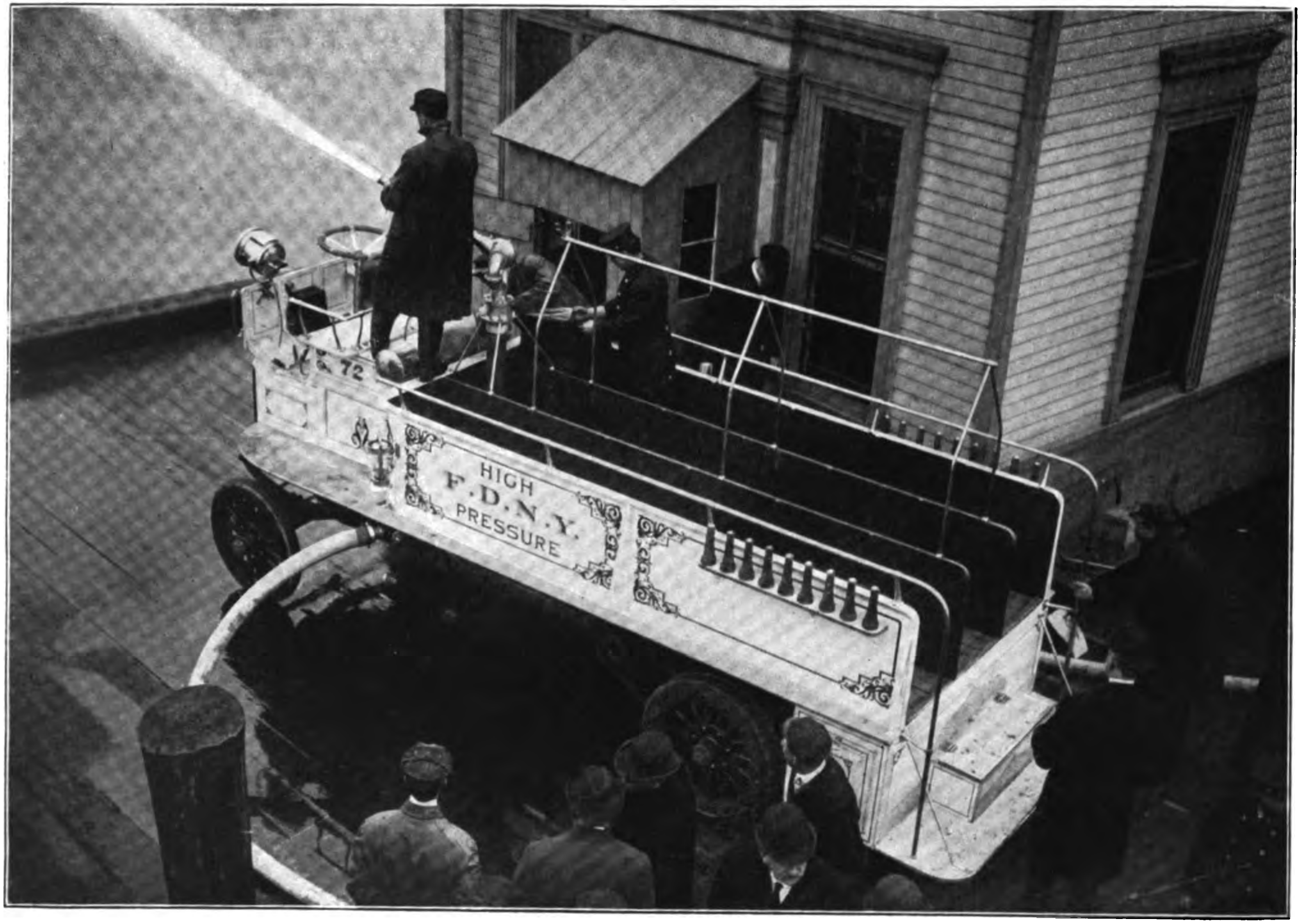
Fig. 20. Charging Plug.

without jerk or strain, which are detrimental to the life and efficiency of every part of the vehicle. The motor is designed along the same lines as have proven so successful in street railway work. It has a very heavy shaft, simple and durable brush rigging, and is wound to show not alone a high efficiency, but also a high capacity for overload. The armature shaft is carried on annular ball bearings which tend to greatly increase the efficiency of the motor as a whole. It is suspended on a transverse bar pivoted to the side members of the frame, forward of the rear axle. This pivoted suspension keeps the motor shaft parallel with the countershaft throughout the entire range of chain adjustment and permits the use of an efficient silent chain drive.

Transmission. The entire countershaft is housed-in and is carried on four taper roller bearings inside the tube, the latter being held in self-aligning ball sleeves in hangers riveted to the sides of the frame. The two short driving shafts are connected by a spur differential and carry at their outer ends small sprockets for the roller chains to drive the rear wheels, the entire countershaft being a complete unit. It is driven by a silent chain of ample width running over a small pinion on the motor and the gear of the differential. The battery capacities are 112 ampere hours for the one- and two-thousand-pound delivery wagons, the motor of the former developing its power at 2,000 r. p. m., while all the others run at 1,200 r. p. m. The 2-ton truck has a battery capacity of 168 ampere hours, the 3½-ton truck, 196 ampere hours, and the 5-ton truck, 280 ampere hours. The controller in every case, provides four speeds ahead and two reverse.

SPECIAL FORMS OF THE ELECTRIC

Couple-Gear Truck. Owing to the ease and directness with which the power may be applied, electricity lends itself admirably to special forms of construction, a particularly ingenious example of which is to be found in the drive of the Couple-Gear truck—so-called because all four wheels are driven by electric motors and all are utilized for steering purposes. These vehicles are built as straight electrics, using a storage battery as the source of current; and as gas-electric vehicles, a gasoline engine and generator forming the power plant, the remainder of the design and construction being the same in both cases.



AUTOMOBILE FIRE TRUCK LINKED WITH NEW YORK CITY'S HIGH-PRESSURE SYSTEM
Official Test by Chief Croker.

The motor is built directly into the wheel, as will be apparent from the illustration of a dismounted wheel shown in Fig. 21. The motor is of bipolar type, designed with flat fields in order that it may fit within the wheel without unduly increasing its section and is held by its attachment to the axle. The wheel accordingly revolves about the motor, being driven by the two small pinions noticeable on opposite ends of the armature shaft, and which mesh with the circular racks attached to the periphery of the wheel. The brushes are carried in a yoke bolted to the outer half of the field casting, so that the removal of the latter makes everything accessible. The appearance of the complete wheel, minus its tire, will be apparent from Fig. 22, which shows it end on, and also serves to illustrate the drive, one of the pinions meshing with a rack on the inner half of the wheel, and the second with the outer half. The electric cables for conveying current to the motor are led through the hollow axle. Apart from this feature and the employment of a four-wheel steer, the vehicle itself follows more or less conventional lines.

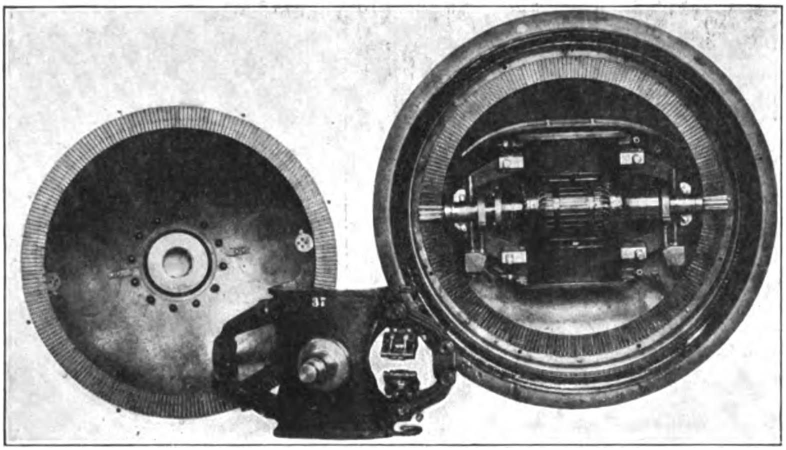


Fig. 21. Dismounted Couple-Gear Truck Wheel Showing Motor Parts.

Lansden Scenery Wagon. The scenery wagon, Fig. 23, has a load capacity of 4,000 pounds and measures 20 feet 6 inches over all; it is also designed to haul a small trailer behind it to support the unusually long scenery employed in the Metropolitan Opera House. The tread is 66 inches, and the wheel base 148 inches, and

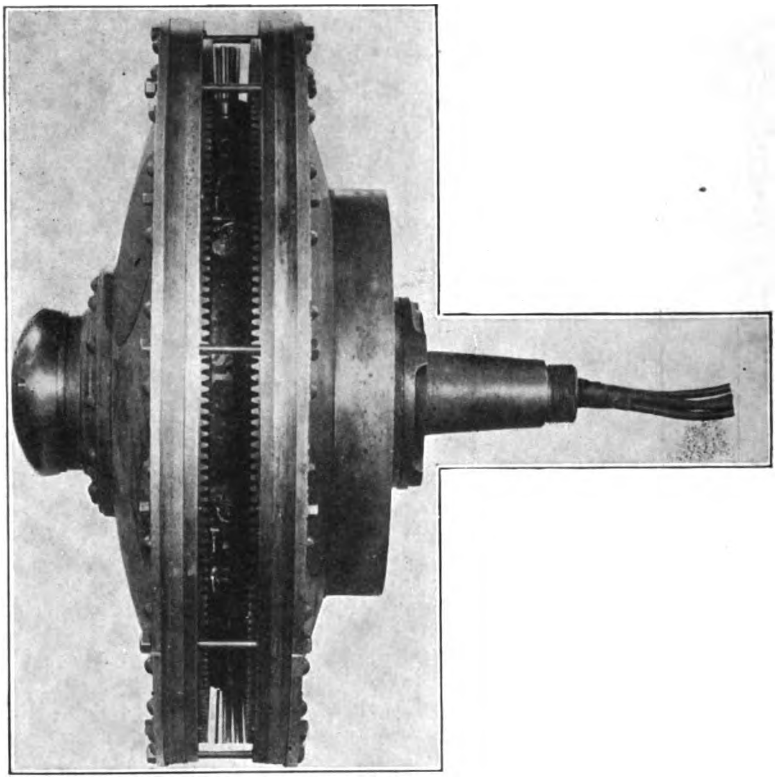


Fig. 22. Assembled Couple-Gear Wheel with Tire Removed.

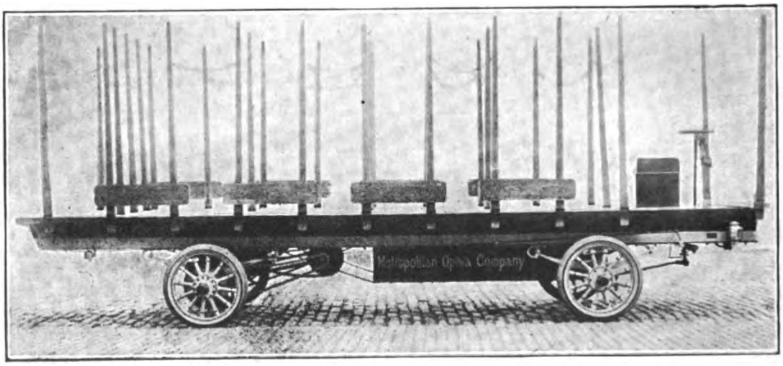


Fig. 23. Lansden Special Scenery Wagon.

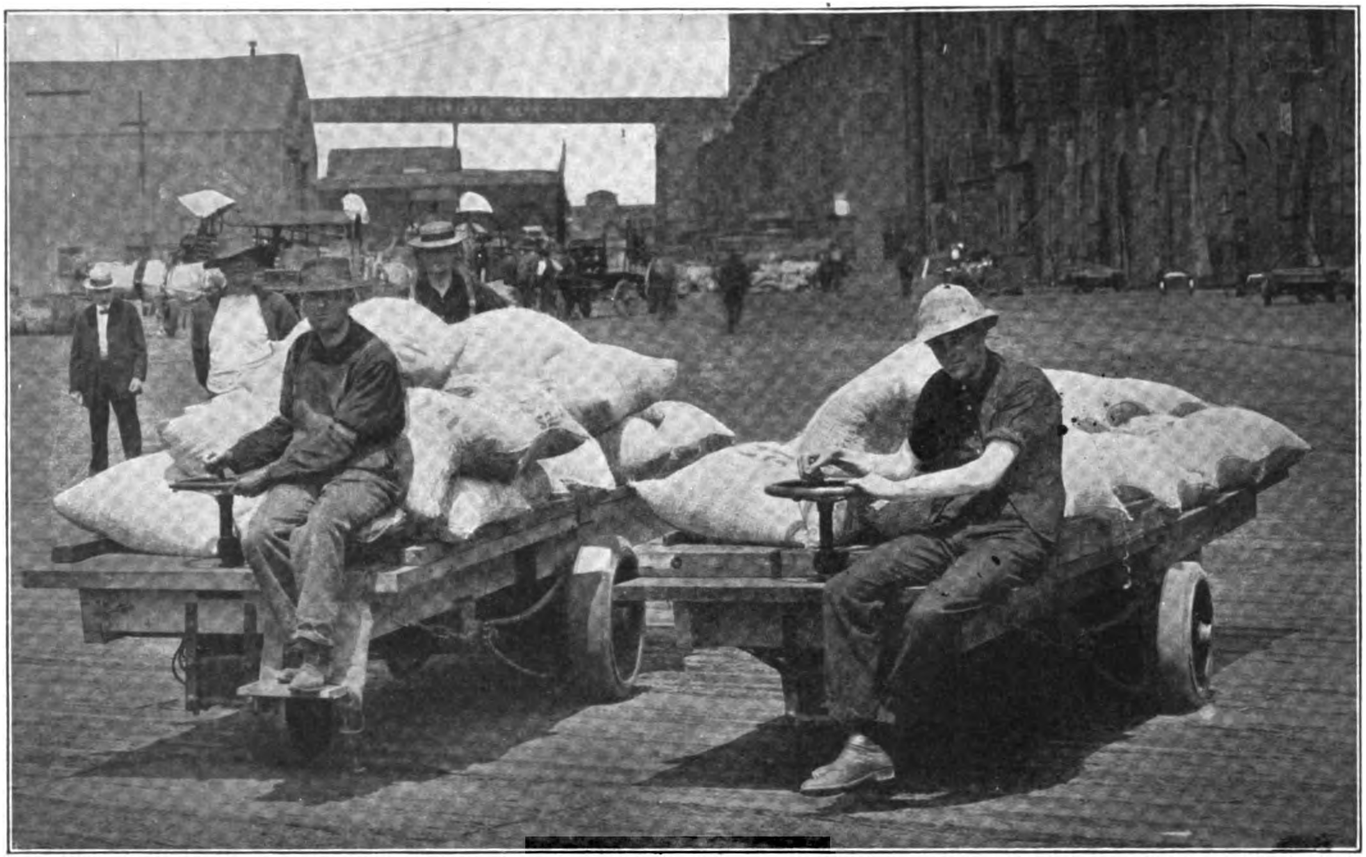


Fig. 24. Electric Dock Trucks.

the weight of the vehicle 5,000 pounds; the tires are 32-inch by 4-inch solid rubber, and the chassis in other respects is of the same construction as the regular delivery wagons listed by the same makers. The motive power is a single motor fed with current from a 60-cell Edison battery.

Dock Trucks. A special and very serviceable type of electric truck has been developed for use in handling cargoes. Fig. 24 shows two of these trucks in action, and gives an excellent idea of their characteristics. These dock trucks are built on a special convertible system by which they may be readily supplied as either single or double-ended cars. A plan view of the double-ended type of chassis is shown in Fig. 25. One of the special features of this vehicle is the fact that it may be interchangeably driven from either end, by simply lifting out the steering column which carries the wheel and controlling lever with it. There is a controller at each end and a special switch governing the direction in which the vehicle will run. The method of interchangeable steering will be apparent at a glance at the illustration. The load capacity of these trucks is 4,000 pounds and they are capable of running 18 miles on a charge of the battery at a speed of 4½ miles per hour. The weight of the car complete is 2,750 pounds. The driving wheels, 24 inches in diameter, and shod with 6-inch rubber tires, are placed in the center of the chassis, while at each end a single steering wheel of smaller diameter is provided with steel tires. The platform space is 14 feet 6 inches long by 4 feet broad, and stands 28 inches above the floor. Several of the same type of truck are also in use as baggage transfer wagons in railway terminals.

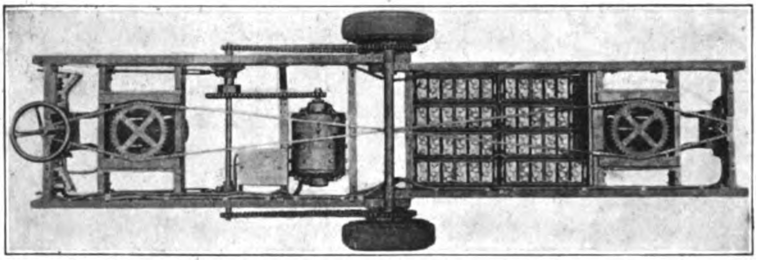


Fig. 25. Double-Ended Dock Truck Chassis.

GASOLINE VEHICLES

TAXICABS

Development. Looked upon generally as being nothing more or less than a slight modification of the pleasure automobile, the taxicab has, in reality, proved to be one of the most important factors in the development of the commercial vehicle as a type. Automobile designers were of the opinion at the outset that little else but size distinguished the touring car from a vehicle adapted to public service. European designers undertook to proceed along this line as far back as 1904 and were grievously misled thereby. It did not take long to demonstrate that there was a world of difference between an automobile intended for occasional service, even though the latter be hard, and one that would be called upon to work ten to eighteen hours a day, in all kinds of weather, and every day in the year.

New York was really a pioneer in the adoption of the motor-driven cab, as they were to be seen on the streets of this metropolis as early as 1899. They were not taxicabs, simply because they were not provided with the distance- and time-recording meter that has been responsible for the creation of that appellation, but they were probably the first motor-driven vehicles to be employed in this service. Electricity formed the motive power and the vehicles themselves were of the hansom type with the driver seated on top or behind, according to the precedent established by the horse-drawn hansom; later, coupés, victorias, opera buses, and the like, were used.

These vehicles were placed in service at a time when neither the batteries nor the method of transmitting the power to the road wheels had reached a high state of development; they were accordingly inefficient as compared with later-day cabs, but they were very solidly built, as is shown by the fact that many of them are in active service right up to the present. That their earning power is low as compared with the gasoline vehicle, due to the higher cost of operation, goes without saying, but they appear to be destined to remain in service for some time, so far as can be judged at the present writing. When first employed, the electric vehicle was the only type that could be depended upon to provide reliable service, and the delay in adopting gasoline-driven cars for this service was a result of their shortcomings in this respect. Only one company attempted their use on any scale in this country, and was responsible shortly afterward for their introduction abroad.

Despite the numerous points of similarity between the average touring car and the public service vehicle, French designers, who were the first to attempt a gasoline taximeter cab service, found that there were many lessons to be learned. These first attempts were accordingly not always of the most profitable nature, but they served to give their promoters much valuable experience upon which later developments have been based.

The gasoline taxicab was not introduced into this country until 1907, and, as was to be expected, the first cabs came from abroad, a company starting in New York with about 150 vehicles the first year. How great has been the growth in the few years intervening is illustrated by the fact that New York alone now has more than a dozen companies operating between two and three thousand cabs—which are not always sufficient to supply the demands by any means.

Competent Drivers. With the taxicab, just as with all other gasoline-driven vehicles in the commercial field, the procurement of a sufficient number of skilled drivers to handle the cars proved at the outset a greater difficulty than the designing of a car suited to the service. In view of the extremely rapid growth, the demand for such men has naturally been entirely disproportionate to the supply, applicants in a very large number of instances being nothing more than hack drivers whose only asset is a chauffeur's license from the state.

The capacity for destructiveness of the green drivers was further added to by the system of remuneration first in vogue—that of paying the driver entirely on a commission basis. In New York, this was 20 per cent of the net earnings of the cab, the driver paying for the fuel used at cost; while in Europe a nominal wage was paid, supplemented by percentages on a sliding scale in accordance with the earnings of the cab. In every case, this was controlled by the taximeter which provided an accurate check on the day's work by recording the total distance run and the sum received by the driver.

Taximeters. The Jones taximeter, Fig. 26, was the first instrument of the kind to be manufactured in this country, and as all taximeters work on the same principles and are substantially alike in construction, it will be unnecessary to refer to others. A series of

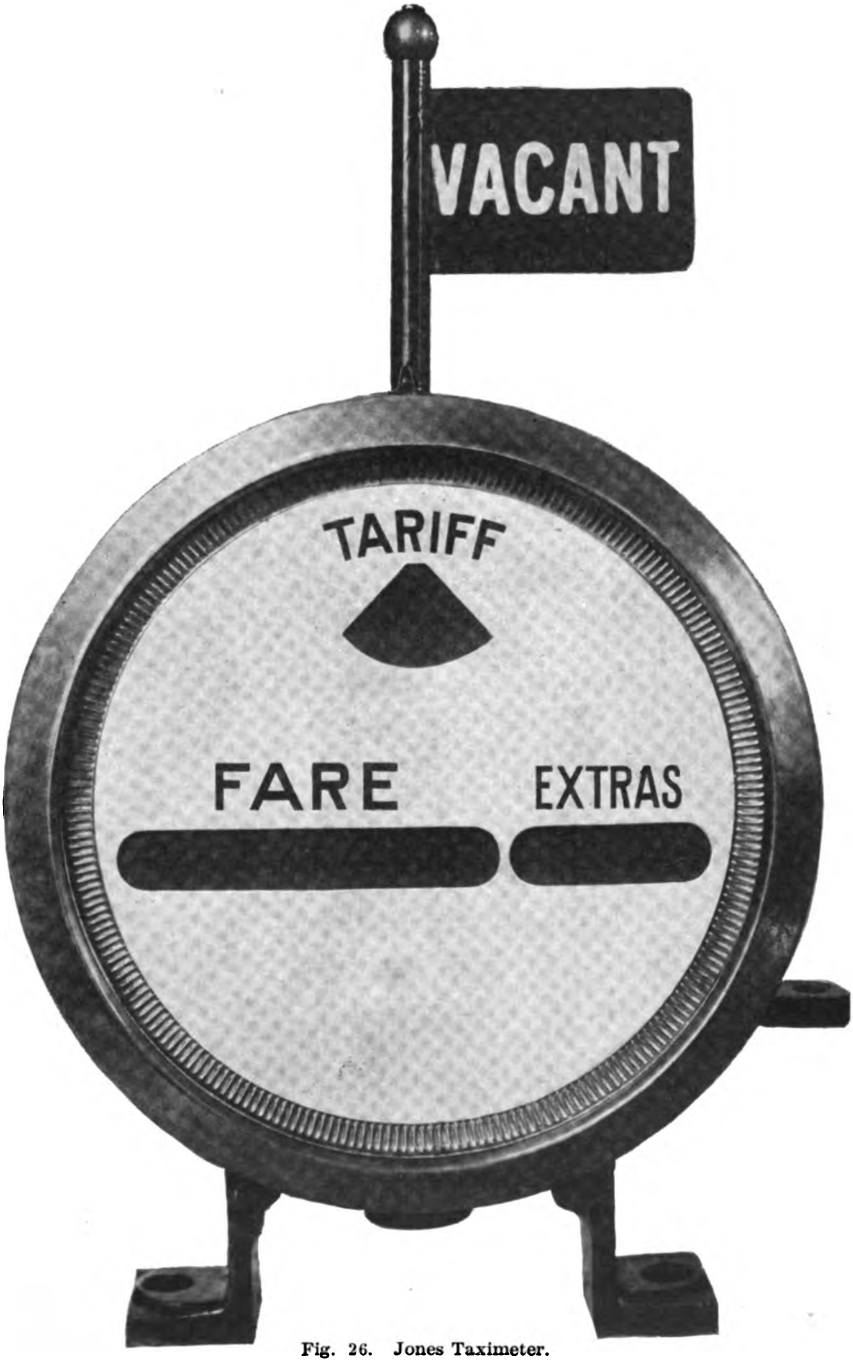


Fig. 26. Jones Taximeter.

numbered dials, carrying the figures on their edges, are actuated according to their decimal values on a dollar basis, by a flexible shaft connection with one of the wheels of the cab. Formerly one of the driving wheels was utilized for this purpose, but due to the slip of the latter on wet pavements or ice, a mileage greatly in excess of that actually traveled was often recorded, and the objection raised by the public was so general that the driving mechanism was transferred to a front wheel. As is the case with the ordinary speedometer, the instrument's working is based upon the diameter of the wheel by which it is driven. For instance, assuming the circumference of a 30-inch wheel to be 90 inches—in round numbers for the sake of illustration—it would make 704 revolutions per mile, no deduction being made for slip. This number of revolutions would cause the first dial to revolve once and the rate per mile to appear at the first opening. For example, on a basis of 30 cents per mile, the latter sum would show; but as this is the minimum charge, the taximeter is arranged so that when the engaged lever is put down, this charge appears. After the first mile the dial is arranged to record quarter miles, at the rate of ten cents, usually. Extras, such as carrying baggage or going beyond the limits of certain districts, are manually recorded on the taximeter by the driver, and a second series of recording dials, the figures of which are visible through openings in the rear of the instrument, indicate the total amount received.

Operating Costs. *Repairs.* While from the first, earnings have been large, some of the drivers have been able to damage the cars faster than the shops could repair them; and the lack of experience in the handling of the machines has also resulted in frequent accidents, so that operating costs have been correspondingly high.

Immunity from repairs, or at least a reasonable freedom from breakdown, is of vital importance in the operation of any commercial vehicle, but especially so in the taxicab. These little cars average 80 to 100 miles per day, and in the hands of particularly ambitious drivers have been known to run as high as 125 to 150 miles for days in succession. As the driver is working in his own interest, he is naturally tempted to get there and back as quickly as possible, in order to cut down his waiting time to the minimum. The result in the first year of operation was a list of repair charges that was appalling. Stripped gears, battered radiators, damaged bodies, and the like were of such frequent occurrence that a considerable percentage, in fact, an excessive fraction of the total equipment was always in the shop. Seized motors were not unknown as factors in this list, as some of the novice drivers found even the absolutely simple lubricating system employed beyond their comprehension. This trouble was so general that a rule was enforced making it compulsory for the driver to always feed sufficient lubricating oil to keep the motor smoking. Such a procedure would have led to endless trouble in Paris where it is a misdemeanor to permit smoke to issue from the muffler; but in New York no such ordinance existed, and with the increase in the number of cabs, the smoke nuisance became flagrant, for the companies found it more economical to let the motors smoke, due to the excessive lubricant, and give them a periodical overhauling and cleaning, rather than to be called upon to repair them at short intervals owing to a lack of oil.

Tires. The advent of the taxicab in large numbers also served to give the pneumatic tire an entirely new status. Previous to that time, this was generally looked upon as the most unreliable and costly part of an automobile; but for commercial service, pneumatic tires are not bought outright as is the case with the individual user. The companies contract with the tire manufacturer for their equipment entirely on a mileage basis. That is, the tires are supplied as often as needed, compensation being calculated only on the mileage they run, so that whether a tire gives long service or fails after a very short time, it does not cost the user any more, every tire being numbered and a record of its mileage kept by an employe of the tire maker, this being made possible by the taximeter. The system goes far toward showing how erroneous the prevailing impression of tire weakness is, as it proves that pneumatics may be guaranteed for a certain mileage on a working commercial basis. The recording instruments are also leased and are kept in order by the manufacturers. At the outset, delays from puncture were guarded against by providing all the cabs with a *Stepney spare wheel,* which consists of a special rim carrying an inflated tire and provided with lugs which permit it to be bolted directly to the wheel in a few minutes, but this does not appear to have met with general adoption. The spare wheel was put in place without attempting to remove the damaged tire, and the driver's instructions were to return to the station for a new tire as soon as possible after the puncture occurs, though there is nothing to prevent the spare wheel from being run for considerable distances on either the front or rear wheels with perfect safety.

Requirements of Service. It may appear at first sight as if the foregoing were more or less irrelevant, particularly in a work devoted largely to design, but its bearing on the subject will be realized from the description of the cabs in use, both their design and construction having been influenced to a very great extent by the experiences outlined above. Either because they failed to recognize the limitations of the average touring type of vehicle for this purpose, or because they were too busy producing the latter to be able to devote attention to the development of a new type, American makers were not prepared to meet the demand when it first arose. As a result, foreign manufacturers supplied the first two American cab companies with their vehicles and in this manner obtained such a hold on the market that quite a substantial percentage of the entire foreign car imports have consisted of cabs for the past three years. Judging from the nature of the experiences related of their early use, it is evident that several things were demanded of the successful taxicab that were not of such great importance in the touring car. Chief among these is the requirement of absolute *simplicity,* which means the absence of all necessity, or, in fact, possibility of adjustment by the driver. Then follows *compactness, ease of handling,* and *ready interchangeability,* as in such strenuous service as the cab is called upon to perform, the need for repairs is more or less frequent, even in the hands of the most careful drivers.

Types. *Foreign.* Practically all of the first cabs to see service in this country were of French origin, these being, in the order of their numerical importance, the Darracq, De Dion, and Delahaye. It will be noticeable from the description of the Darracq and that of some of the more prominent American cars of this type, that makers in this country were quick to take advantage of the results of the experience of their foreign confrères. The Darracq motor is of the four-cycle, four-cylinder, vertical type, with the four cylinders, as well as a large part of the piping for the inlet and exhaust, cast in a single piece, a practice that has since been followed largely here, in light touring car, as well as cab, design. This eliminates practically 90 per cent of the usual piping, the inlet and exhaust passages being cored right out of the casting, the necessary cooling of the latter being obtained by casting radiating flanges on it. Only two short lengths of pipe are necessary between the water jackets and the radiator for the circulation of the cooling water.

Designed in this manner, the motor becomes virtually a block which is mounted so as to be readily taken off or replaced on the chassis, and as its cylinder dimensions are very small (3.3 inches bore by 3.9 inches stroke), the motor as a whole is very compact. Such cylinders as these appear puny beside those ordinarily employed in pleasure-car design, but the object has naturally been to keep the power and weight down to but slightly more than what are actually needed. A motor can only approach its maximum efficiency when run under an approximation to its full load, and where a large amount of excess power is provided for as in the touring car, this is not possible, particularly in city streets with their close speed limitation and frequent necessity for slowing down and stopping. This small motor develops 18 horse-power, which is ample, and is of course, very economical in its consumption of fuel and lubricating oil, which represent very substantial items of expense in the running of a large number of machines.

A Bosch high-tension magneto comprises the sole provision for ignition, thus reducing the wiring to the simplest terms. It is located under the exhaust manifold, an easily accessible, but out-of-the-way place, this being an otherwise bare side of the motor as all the valves are placed on the opposite side. The sparking point is fixed, but may be retarded for starting by pulling a small trigger located near the cranking handle, so that the entire control of the motor is centered in the throttle lever, which takes the form of a pedal, in order that the driver may have both hands free for steering and manipulating the change gear lever. Driving is thus reduced to steering, braking, and operating the clutch and gear-shifting lever.

The power plant, consisting of the motor and clutch forward, constitutes one easily handled unit, while the drive is a second, the gear box being mounted on the rear axle. Three speeds forward and reverse are provided, gear-changing being by means of the usual lever operating in a gate sector, and the entire transmission may be taken down or replaced with the same ease as the motor, simplicity and interchangeability having been attained by uniting the differential and gearset in the same housing on the rear axle. In addition to the switch and pressure feed lubricator on the dash, there is a small lever by means of which the exhaust may be made to pass through a foot warmer in the floor of the body before reaching the open air. The wheel base is short and the frame is made as narrow as possible forward, so that the cab may be turned round in the ordinary narrow cross-town street without resorting to the reverse. This makes the cabs exceptionally easy to handle in congested traffic, these features having been brought about largely through the rigorous traffic regulations of the London police, as the first of these cabs were designed for service in that city.

American. The chief source of trouble with the majority of American taxicabs first placed in service was due to the fact that they were not taxicabs at all, but merely touring chassis fitted with landaulet bodies and taximeters—in fact, the addition of the recording instruments appeared to be the only thing necessary to accomplish the conversion. But the demand for power-driven, public-service vehicles has been so great that a large number of these makeshift cars have been run profitably.

The Thomas taxicab was one of the first of American production to be designed especially for this purpose, and as will be noted from its specifications, its builders were careful to follow the precepts learned through costly experience by foreign makers. It is equipped with a four-cylinder vertical motor cast *en bloc*, with the inlet and exhaust passages integral, the latter being cooled by radiating flanges cast right on it. The cylinder dimensions are $3\frac{3}{8}$-inch by $4\frac{5}{16}$-inch bore and stroke respectively, with an output of 16 to 20 horse-power. The valves are all placed on the same side and amply water-jacketed, as are also the exhaust manifold and the carbureter, the latter being of the simplest automatic type. The flywheel has blades attached to its periphery to act as a fan, while a pump is dispensed with, the water circulation being on the thermo-siphon principle. Ignition is by the Bosch high-tension magneto with fixed sparking point, the control being confined to a throttle lever on the steering wheel and a pedal accelerator. Lubrication is provided for by a pressure operated oiler mounted on the dash. The complete motor and clutch, which is of the three-disk type using cork inserts, is a simple and compact unit, mounted on a three-point suspension to relieve it of any stress that would otherwise be imposed by any bending of the frame.

Drive is by propeller shaft, the gearset, differential, and bevel gears all being centered in the same housing which serves to enclose the live rear axle. The brakes are unusually powerful and are placed in drums on the rear wheels. Suspension takes the form of full elliptic springs in the rear and semi-elliptic springs forward. The steering gear is of the worm-and-sector type with easy provision for adjustment to take up wear, as is the case with every other part of the mechanism that is apt to develop looseness, while the complete units may be readily dismounted in a short time and replaced. The wheel base is 103 inches, wheels 32 inches in diameter, and tires 4 inches all round. Eight gallons of water are carried in the radiator, one gallon of lubricant in the pressure oiler, and 14 gallons of fuel, the economy of these cars being demonstrated by the fact that one of them covered 22.7 miles on a gallon of gasoline in the economy test held under the auspices of the Automobile Club of America in 1909.

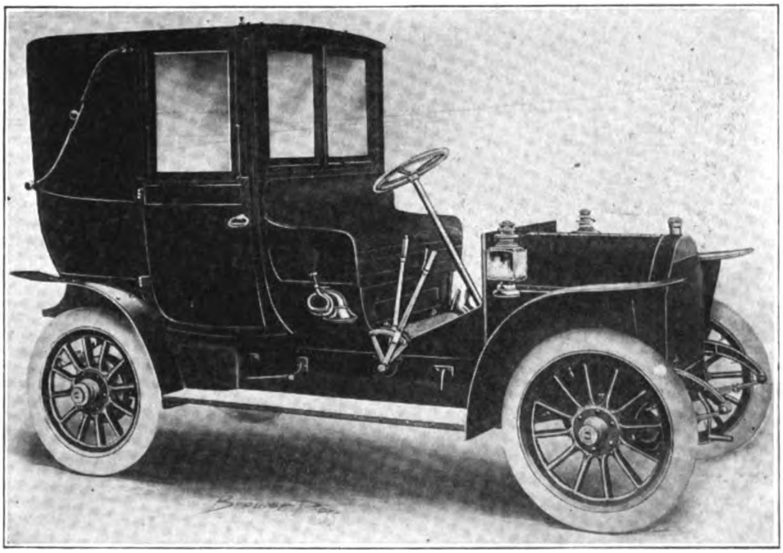


Fig. 27. Alco 4-Cylinder, 16-H. P. Taxicab.

For a number of reasons, the principal one of which has doubtless been the system of compensation, taxicab drivers have had a strong incentive to speed their cars and much of the damage suffered by taxicabs in service has risen from this cause. The designer of the Alco taxicabs, Fig. 27, has accordingly specified a maximum speed of 800 r. p. m. for the four-cylinder motor which forms the power plant of these cabs. At this speed, it develops 16 horse-power, which is ample for the purpose, and has the further advantage of not permitting the cab itself to be driven at a speed exceeding 20 miles an hour. This is the same motor that is employed on the Alco 3-ton truck, but in the latter case it is speeded higher and develops 24 horse-power. In both cases, the motor speed is automatically controlled by a throttling governor that cannot be tampered with by the driver. A Bosch high-tension magento is employed for the ignition, while lubrication is by splash, the supply being constantly replenished by a force-feed oiler. A sliding gear transmission of the selective type provides three forward speeds and reverse, final drive being by propeller shaft to a live rear axle of special design for cab work. Semi-elliptic springs are used forward and a three-member platform suspension in the rear. The wheel base is 104 inches, gauge

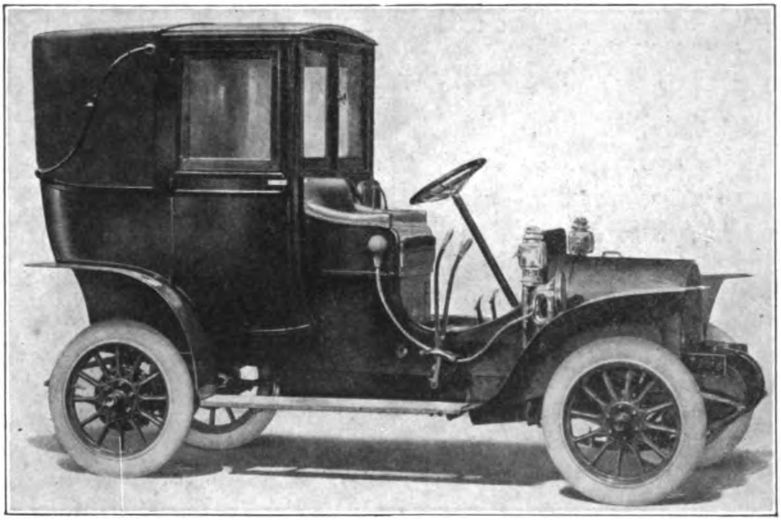


Fig. 28. Franklin 18-H. P. Taxicab—1910 Model.

55 inches, while the tire equipment consists of 32-inch by 4-inch pneumatics all round. The weight of the complete car is 3,100 pounds.

The Franklin taxicab, shown in Fig. 28, has as its motive power a four-cylinder, 3⅜-inch by 4-inch motor, rated at 18 horse-power, and cooled by a flywheel suction fan, as described in connection with the light trucks of the same make. In fact, the chassis is practically the same throughout, its dimensions being modified to suit the changed conditions of service. The ratio of gear reduction on the direct drive is raised to 4.5 to 1 which gives the car speeds in excess of 20 miles an hour. All on, the weight is but 2,250 pounds, so that the tire equipment of 30-inch by 4-inch quick detachable pneumatics, front and rear, is ample.

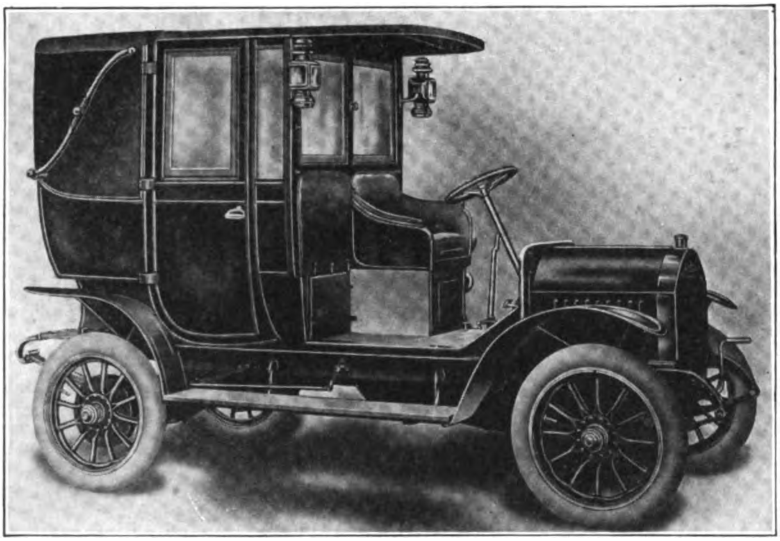


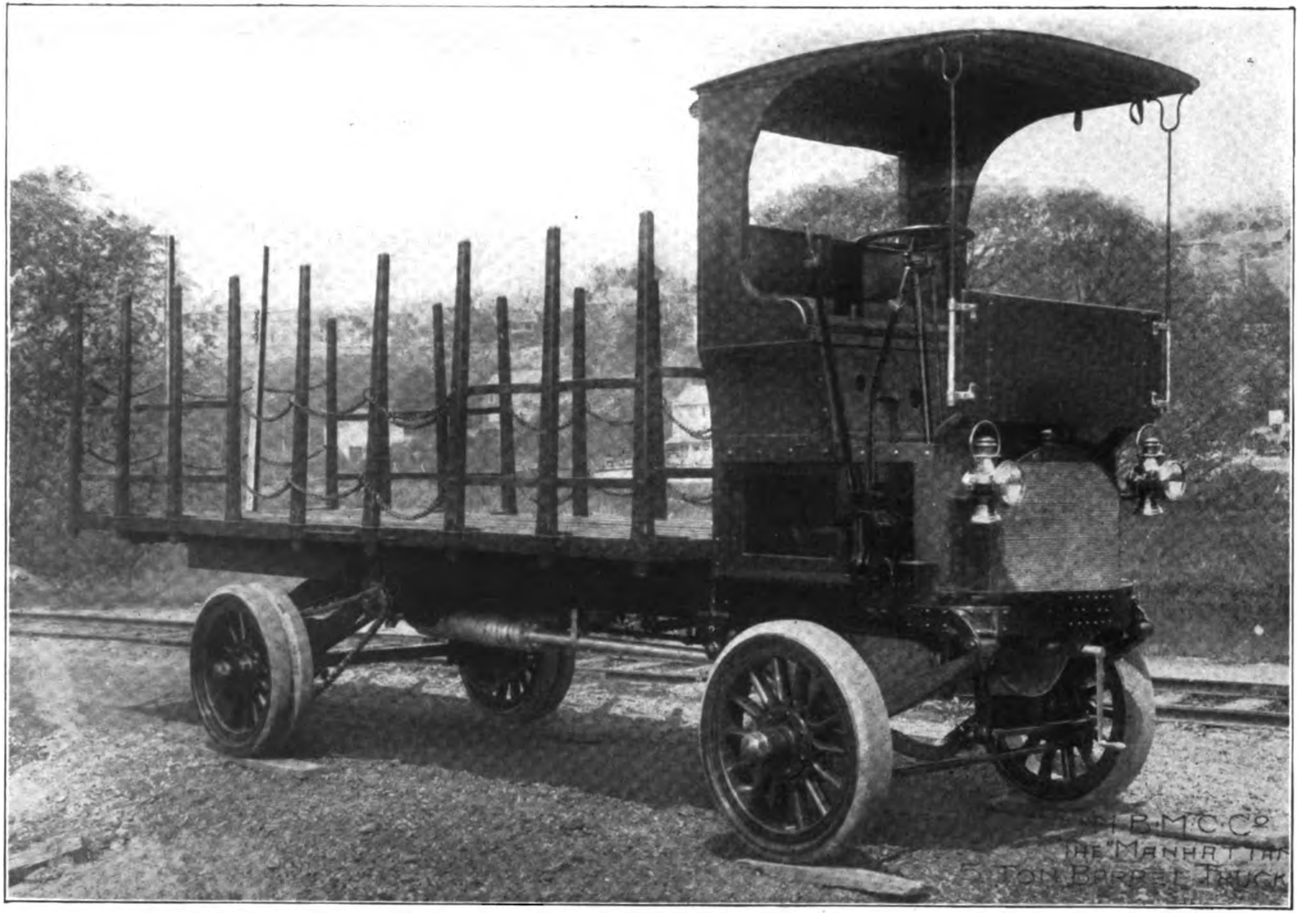
Fig. 29. Altas 2-Cycle Taxicab.

The standardization of a chassis and power equipment for various forms of light to medium commercial service as shown by the American and Franklin trucks and taxicabs, is also to be found in the Atlas taxicab shown in Fig. 29. This is fitted with the same two-cylinder, 20-horse-power, two-cycle engine as that described in connection with the Altas delivery wagons. Owing to the extreme shortness of the motor, only a small hood is required and ample space is allowed for the driver without the necessity of increasing the wheel base to accommodate a good sized landaulet body. Three-quarter elliptic springs are employed for the suspension in the rear, this, apart from the difference in dimensions and the fitting of pneumatic tires, constituting the only change of importance between the specifications of the cab and the delivery wagon. As shown in the illustrations of both the Franklin and Atlas taxicabs, it is customary to fit these vehicles with an individual driver's seat, the latter being on the left-hand side, in order to provide accommodation for a trunk or other baggage. A folding seat gives accommodation for an extra passenger when the space is not utilized for baggage.

GASOLINE DELIVERY WAGON

It will be found on a brief examination of the subject that this is a far more comprehensive heading than would appear at first sight, as it includes everything from the little three-wheeler up to the type known as the *light truck* but which is, in reality, also a delivery wagon with an open platform, or stake type of body. The range of carrying capacity is from one or two hundred pounds up to one ton, or slightly more, as many delivery wagons and light trucks are built with a load capacity of 2,500 pounds, or even 3,000 pounds.

Package Delivery Motorcycle. At the lower end of the range is to be found a hybrid type, consisting of all the elements of a motorcycle, minus the front wheel, for which is substituted a package-carrying box of light construction mounted on two wheels. This, of course, does not represent any closer approach to a true type of commercial vehicle than does the touring car chassis fitted with a second-hand landaulet body and a taximeter represent a practical and efficient taxicab. The motive power of this hybrid consists of a 2- to 4-horse-power, single-cylinder, air-cooled motor of the four-cycle type, driving the single rear wheel by a chain and having but one speed. As the entire machine weighs only a few hundred pounds, it is readily pushed backward, and so has no need of a reverse, while the power provided is ample and there is no necessity for a change-speed gear. It is started by pedaling and stopped simply by shutting off the ignition current, a coaster brake such as is used on bicycles and motorcycles being sufficiently powerful for all needs. The package body is of the lightest possible construction and its load-



FIVE-TON, OIL-BARREL TRUCK
Mack Bros. Motor Car Co., Allentown, Pa.

carrying capacity is little more than nominal where weight is concerned. It is naturally intended merely for the quick delivery of comparatively small and very light packages, and in this rôle has proved successful to a limited extent. Low initial cost as well as the extremely economical expense of operation and maintenance are, of course, its chief advantages, and these naturally recommend it to the small shopkeeper. On the other hand, it has so many disadvantages that it is safe to say, its use is not at all apt to become general, even in this limited field. Both the rider and the mechanism are entirely exposed to the weather, and the machines, at least as built thus far, have not been designed with a view to commercial service.

Standard Delivery Requirements. Before taking up a description of the different examples of gasoline delivery wagons as an illustration of the various angles from which solutions of the problem presented by this highly important branch of commercial service have been attempted, it may be well to briefly summarize some of the principal requirements of the problem itself. They are exactly those which have been dwelt upon as being essential to the successful taxicab. The object to be attained is the same—a vehicle of the most reliable, efficient, and economical type and so simple as to be readily operated by an unskilled driver, the only difference really being in the nature of the load to be carried.

Simplicity of Design. This naturally involves the designing of the power plant and the drive as independent units, and more particularly the former, in order that the entire vehicle may not be placed out of commission, simply through some minor defection, which, though of relatively small importance, involves considerable delay in its repair. All functions of the motor must be as nearly automatic as it is possible to make them, little or nothing in the way of adjustments being left to the discretion of the driver. Ease and simplicity of operation must characterize the clutch and the gearset, and every part must be of as durable construction as is possible to make it. In fact, the design and construction must be such that the driver's duties are confined almost wholly to starting, stopping, and steering, the vehicle running all day without further need of attention to any of its adjustments than can be given by the skilled attendants at the station before starting out. The ignition system is accordingly self-contained and independent, operating with a fixed point of firing, and may only be retarded for starting; lubrication is entirely automatic and a pump is generally dispensed with, the circulation of the cooling water being on the thermo-siphon principle with an ample volume of water to secure adequate cooling under the most severe conditions. Simplicity has been attained in high degree by the adoption of a planetary type of gear set for the transmission, and this form, while slightly less efficient as compared with the sliding type, has proven very successful in the hands of unskilled drivers, as it cannot be abused. So far as the remainder of the chassis is concerned, solidity of construction within necessarily defined limits of weight, is naturally the chief characteristic, as very liberal provision for durability is imperative in view of the racking stresses imposed by heavy loads being carried on solid tires over rough pavements at high speeds, as compared with the horse-drawn vehicle.

Load Efficiency. While dealing with the question of weight, it may be well to point out the fallacies that have obtained on this point in the past, as this item alone has been directly responsible for the failure of many of the early attempts. The majority of the types were entirely too light for the service for which they were designed and simply went to pieces under the pounding. In the attempt to gain the highest possible load efficiency, and this sometimes actually exceeded 100 per cent, all other considerations were overlooked, with the inevitable result. That this is not something belonging entirely to the erroneous practice of an already forgotten past, is strikingly evidenced by the fact that the writer overheard the general manager of one of the largest motor-building companies in the country, seriously discussing the design of a delivery wagon to carry a load of 1,000 pounds on a weight of 1,000 pounds. The discussion took place within the past year. The vehicle was to be equipped with a four-cylinder, four-cycle, vertical motor of the high-speed type, capable of delivering 16 to 20 porse-hower, while the vehicle itself was to have a speed of 20 miles to 22 miles per hour on the level. It was proposed to turn out a large number of these vehicles for milk-delivery service, the assumption being that as this would confine them to city streets, the going would always be smooth and practically level.

On paper, the design appeared to be practical, but had these delivery wagons actually been built as proposed, they would have added but another failure to the long line that had preceded them from the same cause, except that it would have been more widespreading in its effects owing to the great number it was contemplated constructing. No great amount of engineering skill is necessary to perceive their shortcomings. Carrying a load of 1,000 pounds on a total vehicle weight of 1,000 pounds, means an efficiency of 100 per cent, and as there is usually a tendency to over- rather than under-load vehicles in service, this would be still further increased. It is axiomatic in engineering that any such close approach to perfection is not consistent with durability. In other words, it is not practical to attempt to achieve such a high percentage of efficiency, where the limitation of total weight is so small. For instance, it is not difficult to construct a truck weighing two tons, that will be capable of transporting a load of two tons, but where the former limit is fixed at half a ton, it is an entirely different matter.

Furthermore, it is a gross fallacy to proceed on the assumption that a vehicle intended for strictly urban service may be built much lighter owing to the smoothness of the pavement. While asphalted or wood-block paved streets are now in the majority in large cities, they are not all smooth by any means. Holes, car tracks, and protuberances caused by the excavations for pipes and the extremely careless relaying of the pavement at such places, give rise to obstructions that are quite as serious in the stresses they impose on the vehicle, as any to be found on suburban or country roads adapted to the use of the commercial vehicle. A load-carrying efficiency of 66⅔ per cent would approximately represent the maximum practically obtainable with such a light vehicle. In other words, the vehicle to have a useful load capacity of 1,000 pounds, should weigh at least 1,500 pounds, and 1,600 to 1,800 pounds would be more consistent with the high degree of reliability and freedom from breakdown that are so essential in any commercial service. As the size of the vehicle increased, these limits would naturally approach one another more and more closely, until, as already stated, an efficiency of 100 per cent, or very close to it, would be reached in the 2-ton truck and above, as will be noted by some of the weights given later.

As weight increases, speed for the same power must naturally decrease proportionately, so that while the same high-speed type of four-cylinder, vertical motor that has become standard on the pleasure car is frequently to be met with in commercial truck design—in fact, manufacturers of pleasure and commercial chassis often use the identical motor on both—the ratio of speed change is much greater. In pleasure car practice, it is customary to make the gear ratio on direct drive, or high speed, 3½ to 1 for touring and enclosed cars, and 3 or 2½ to 1 on high-powered runabouts, *i. e.*, when driving direct, the motor makes 3½ revolutions for every turn of the road wheels. As the normal speed of the motor ranges from 1,000 to 1,500 r. p. m., or even higher in the case of some of the smaller powers, this gives a speed range of from 4 to more than 60 miles an hour. On the first and second speeds, the gear ratio is usually about 5 and 7½ or 8 to 1, the reverse often being the same as the first speed, and in some cases a little slower, say 8½ or 9 to 1.

When it is considered that on a weight of 3,000 to 3,600 pounds, the seven-passenger touring car seldom carries a load of much more than 1,000 pounds—seven passengers, average 150 pounds = 1,050 pounds—it will be apparent that its load efficiency does not exceed 33⅓ per cent and is usually much less. Furthermore, owing to inability to run, except at short intervals, at anything like an efficient motor speed, the fuel consumption for the load carried, is very high. As load-carrying efficiency and economy in operation are two very important features of commercial car design, it is evident that to realize them, pleasure car practice must be radically departed from.

High Efficiency on Low Speed. Owing to the manner in which the internal combustion motor develops its energy—*i. e.*, by means of intermittent impulses or blows of high unit value, which must be absorbed and "smoothed out" so to speak, by the heavy balance wheel, in order to be available—its torque, or pulling power, is very low at low-turning speeds. A motor designed to have an output of 30 horse-power at a speed of 1,200 r. p. m., will not deliver 15 horse-power at 600 r. p. m. In fact, the efficiency falls off so rapidly with a decrease in the speed, that a drop of 50 per cent in the latter means a decrease of 75 per cent or more in the power developed, so that at 600 r. p. m., the 30-horse-power motor would probably have an output not exceeding 8 to 10 horse-power. Ability to develop the maximum amount of power over the greatest speed range is known as the *flexibility* of the motor, and the internal combustion motor has been vastly improved in this respect during the past decade. However, as this is an inherent disadvantage that cannot be entirely overcome, provision for a change in the speed from the motor to the rear wheels must always be necessary, and it is essential that this be calculated so as to permit of the motor running as close to its normal speed as possible at all times, regardless of the speed at which the vehicle itself is traveling.

In view of the far greater discrepancy between the speed at which the motor must necessarily turn in order to be efficient, and the permissible maximum speeds of the vehicle as compared with the pleasure car, the problem of adapting the speed changes to the requirements is much more difficult. This is further complicated by the fact that the torque of a motor also falls off when its speed greatly exceeds normal. In other words, its efficiency drops when the motor is allowed to race, in almost the same proportion as it does when the motor is run below its normal speed. Commercial vehicle speeds must necessarily be low, not alone to permit of the transportation of heavy loads, but also in order that the car may be able to ascend grades when fully loaded, so that the gear ratio must be calculated to prevent racing on the first and second speeds, as otherwise the starting ability of the vehicle will be low, and it will be necessary to race the motor in hill climbing with consequent overheating. As racing the motor much beyond its normal speed also imposes great inertia stresses on all the moving parts, the importance of avoiding a ratio of gear change that will involve it on any of the speeds will be manifest. Improvements in motor design which have made it possible to reduce the normal speeds of motors ranging from 35 to 60 horse-power as low as 800 to 950 r. p. m. have done much to simplify this problem, so that the car with a motor specially designed for commercial vehicle work has an advantage over one using a touring car motor. This is especially true in the case of the heavier trucks in which the maximum permissible speed of travel seldom exceeds 10 miles to 12 miles per hour.

Pleasure-Car Design vs. Commercial. Consideration of the foregoing will throw considerable light on one of the chief differences between the pleasure car and the commercial vehicle of the gasoline-driven type. It will be apparent that instead of a gear ratio of 3½ or 4 to 1, the highest available on the direct drive will form a close approach to the first speed of the pleasure car, or about 8 to 1, with a corresponding decrease for the starting and hill-climbing speeds, bringing these as low as 22 to 27 turns of the motor for each revolution of the driving wheels, the actual ratio naturally varying with the size and type of vehicle, as controlled by the load to be transported.

Delivery wagons are accordingly designed with speeds of approximately 4 and 12 miles an hour on first and high, where provided with but two gear changes, and of 4, 8, and 15 to 18 miles, where three speeds are available. However, as the delivery wagon is usually designed to carry a comparatively light load, advantage is taken of this to employ a planetary type of change-speed gear. This type is greatly to be preferred on light vehicles in view of the unskilled class of drivers usually employed, as it is not subject to abuse as is the sliding gear type, but it does not lend itself to a three-speed gear as this involves excessive complication. While ordinarily employed on light delivery wagons, it has also been used very successfully on trucks as heavy as 10-ton capacity.

Types. *Brush.* As there is a wide diversity of types of delivery wagons, a study of their design and construction as exemplified by various makes will serve to give a clearer idea of the manner in which the different problems that arise have been met, than any generalization possibly could. At present, the first step above the motorcycle tri-wheeler with its maximum capacity of about 250 pounds, is the Brush 500-pound delivery wagon, Fig. 30, employed by the Federal government for mail carrying, in which it has proven very successful. The motive power of these small cars consists of a single-cylinder, vertical, high-speed motor rated at 7 horse-power. It is of the four-cycle type and water-cooled, and as is the case in pleasure car practice, the entire power-plant is carried forward under a bonnet, which makes it very accessible. Owing to the short wheel base of the car, the driver's seat is directly back of the bonnet—or where the dash would ordinarily be placed—necessitating the location of the steering gear right over the forward axle, as shown, the brake pedal being on the frame and directly back of the steering column. Instead of being centered directly on the chassis, the bonnet is slightly to the right, providing ample space for the driver's feet at the left, where the control is placed. Left-hand control, as it is termed, *i. e.*, the placing of the driver's seat and operating levers at the left instead of at the right, as has been almost universal heretofore, has numerous advantages for commercial work. As practically all the driving is done in traffic, the practice is becoming more or less general on commercial cars, the taxicabs being the first to employ it to any extent, though one or two pleasure cars have been thus equipped for the past two or three years.

The transmission of the Brush consists of a two-speed planetary gear and a countershaft from which the drive to the rear wheels is taken by side chains, as shown. The suspension takes the form of four heavy helical springs, the action of which is controlled by means of a special form of shock absorber, which prevents the recoil of the springs from setting up the continuous jouncing characteristic of this type of spring, and also serves to check the lateral swaying to which the body would otherwise be subject. One of these shock absorbers is placed at each spring. Both front and rear axle are of tubular construction. The total weight of the car is 950 pounds, and as it has a load-carrying capacity of 500 pounds, its efficiency exceeds 50 per cent, which is high for such a small vehicle.

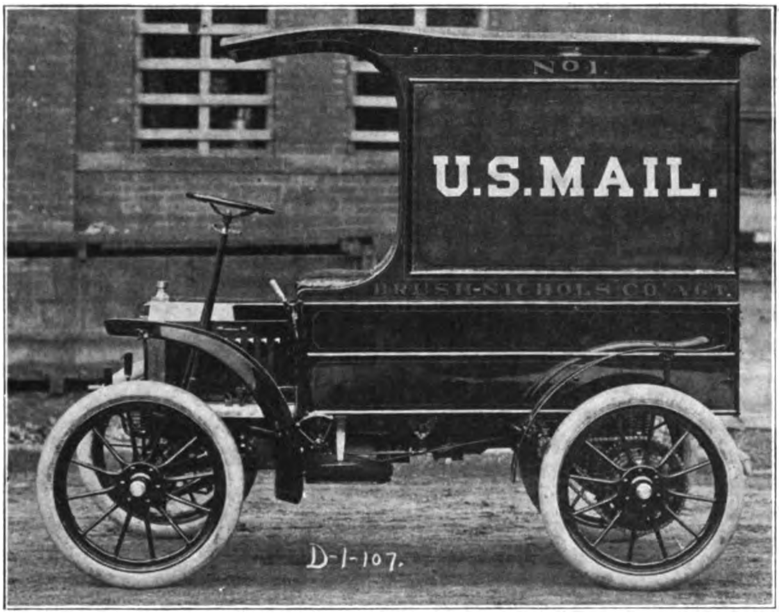


Fig. 30. Brush 500-Pound Delivery Wagon.

Holsman. As the capacity of the usual horse-drawn delivery wagon seldom exceeds half a ton, there are naturally a great number of power-driven vehicles for the same purpose that are rated with a carrying capacity of 1,000 pounds, though the majority of them are actually capable of transporting more than this—in some cases up to 1,500 pounds. A type that embodies many special features is to be found in the Holsman. This is equipped with a two-cylinder opposed, horizontal, air-cooled engine, rated at 12 horse-power.

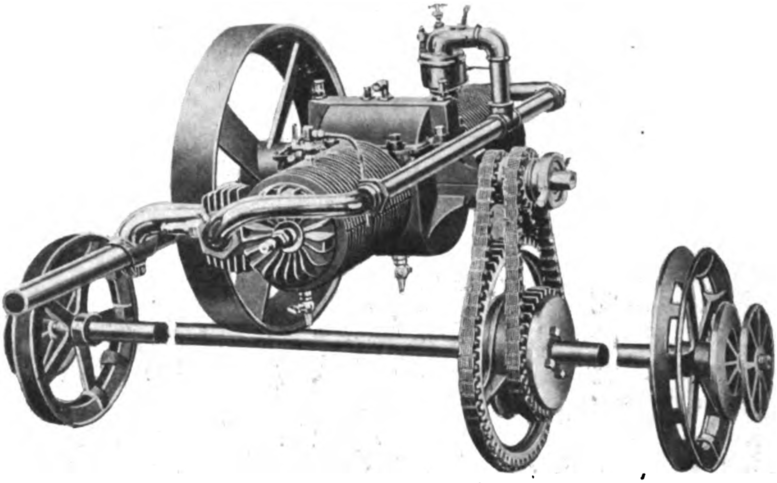


Fig. 31. Holsman 12-H. P., 2-Cylinder Engine and Transmission.

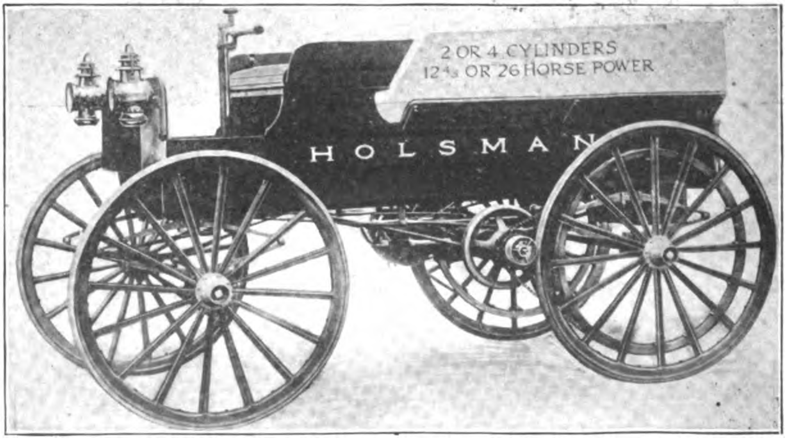


Fig. 32. Holsman High-Wheeled Motor Wagon for Country Use.

It is of the four-cycle type and drives by means of silent chains to a countershaft, as shown in Fig. 31. From the latter, the final drive to the rear wheels is taken by means of steel and manila cables running in grooved pulleys, this construction being illustrated in the complete view of the vehicle, Fig. 32. The suspension consists of full elliptic springs at all four points. High wheels and solid axles are employed, in fact, the whole construction is a close approach to the "horseless" type that was first evolved in automobile design. The control is centered on a vertical column at the right, steering being accomplished by means of a hand lever.

Black. A type that has been evolved directly from the first attempts at pleasure-car design in this country, is illustrated in the plan view of the chassis of the Black 12-horse-power, light delivery wagon, Fig. 33. Except for the employment of an air-cooled motor, this is typical of the arrangement used on the majority of early two-cylinder cars. The engine is placed under the body and parallel with the frame, the planetary gearset being carried directly on an extension of the crank shaft. From the latter, the drive is by means of a single chain to a countershaft and double chains to the rear wheels. The frame is of angle iron, securely braced, and full elliptic springs and solid axles are employed, most of such parts, wheels included, coming directly from the stock of the wagon parts manufacturer. The construction of the motor is shown in Fig. 34, and except for

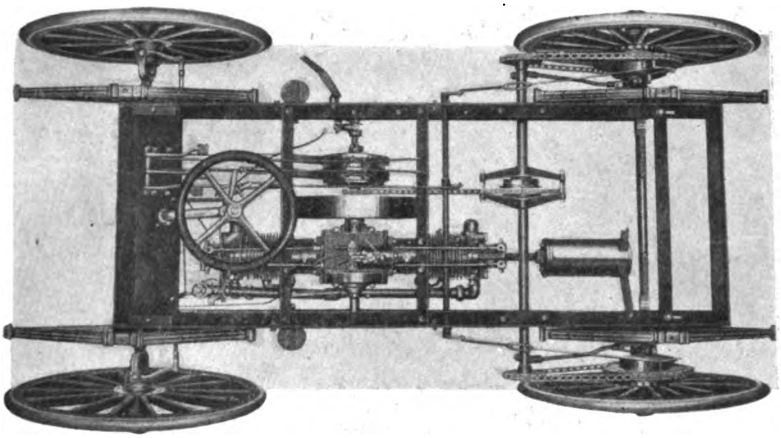


Fig. 33. Chassis of Black 12-H. P., Light Delivery Wagon.

detailed changes, this is, in general, typical of the majority of two-cylinder opposed motors of the horizontal type, whether air or water-cooled.

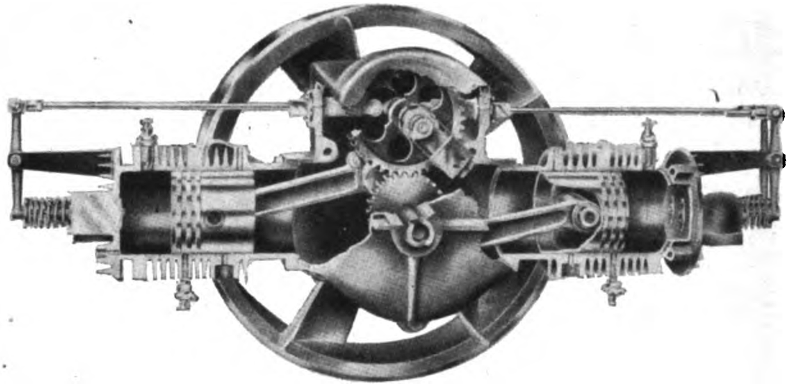


Fig. 34. Black Double-Opposed 12-H. P., to 18-H. P., Air-Cooled Engine.

Reliable-Dayton. An improvement on the foregoing, in that the working parts are much more accessible, is shown in the plan view of the chassis of the Reliable-Dayton delivery wagon, Fig. 35. The motor is placed transversely at the forward end of the pressed steel frame. It is water-cooled and is rated at 20 horse-power. The radiator, of the horizontal tubular type, is hung below the frame, the power-plant being protected by a sloping bonnet, which, when raised, permits of direct access to all parts of the engine. A band

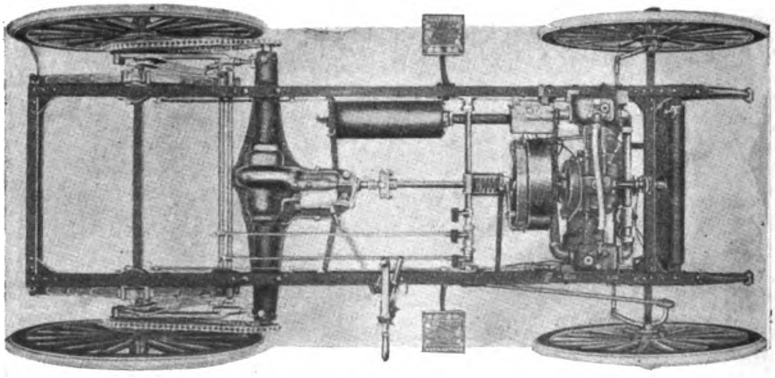


Fig. 35. Chassis of Reliable-Dayton 750-Pound Wagon.

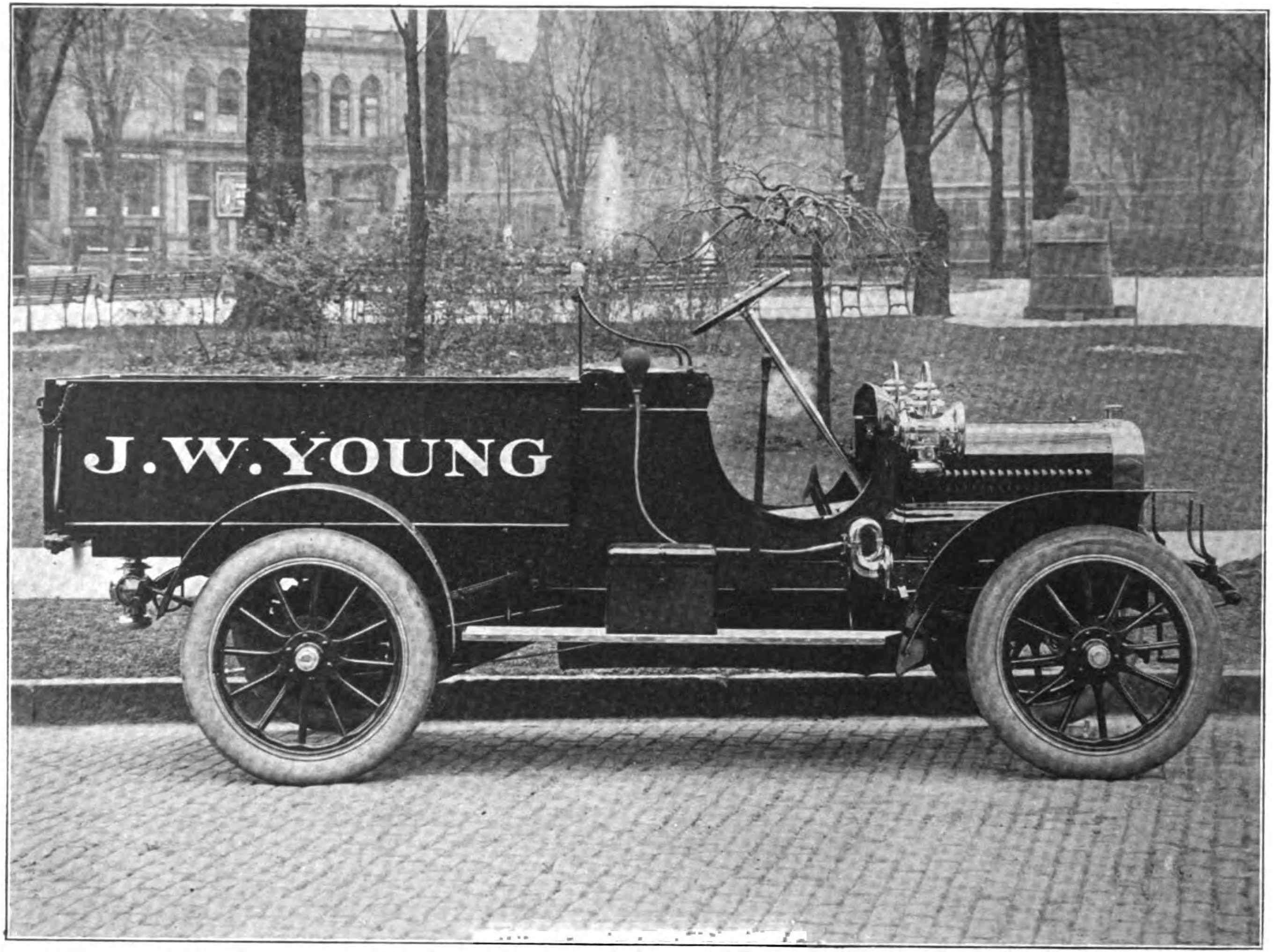


Fig. 36. Cartercar Delivery Wagon.

type of clutch is employed, with shaft drive to a countershaft on which are combined the two-speed sliding gear and differential, these as well as the driving shafts being encased in a light but substantial housing. Final drive is by side chains. Two sets of brakes are employed, operating in drums on the driving wheels. The suspension consists of full elliptic springs at the rear and semi-elliptic forward.

Cartercar. A radical departure from any of the foregoing types is to be found in the Cartercar delivery wagon, Fig. 36. While this employs the standard form of two-cylinder, horizontal opposed, four-cycle, water-cooled motor placed transversely forward, the transmission of the power is accomplished by friction. The details of this mechanism will be apparent from the accompanying illustration, Fig. 37. Through the medium of a short shaft and a flexible coupling at the flywheel end, the motor drives a large disk, running parallel to and in the same plane as the flywheel. Another disk or wheel is mounted to run at right angles to the motor-driven disk, pressing against the latter and traveling across its face, as controlled by the hand lever shown. This wheel is carried on a countershaft on which is also secured the small or forward sprocket of a single chain drive. The large sprocket and differential are mounted on the rear axle, the chain itself being encased to protect it from dirt and water. This chain drive is mounted to one side of the large disk.

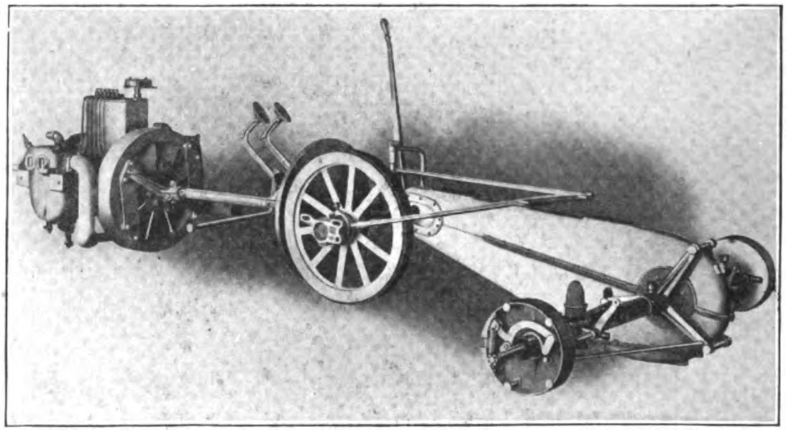


Fig. 37. Cartercar Power Plant and Transmission.

so that the transmission wheel may be moved across its entire face, both the speed and the direction of rotation depending upon the point at which the wheel makes contact with the disk, the center of the disk naturally representing a neutral point. The periphery of the wheel is equipped with a special friction material, which may be replaced at a nominal expense when worn. A transmission of this type provides a wide range of speeds, both forward and reverse, with a very gradual and easy increase or decrease, it being possible to go into reverse while the car is still moving forward, though this is also a feature of the planetary type of change-speed gear. The view of the power-plant and transmission also illustrates the construction of the internal expanding brakes and the rear axle.

In operation, all speed changes are obtained by means of the single hand lever which serves to shift the wheel across the disk. The car is started or stopped by depressing or releasing a pedal on the footboard.

Van Dyke. The Van Dyke 1,000-pound delivery wagon represents another instance in which friction transmission is employed, but in a totally different manner. The two-cylinder, horizontal, opposed motor comprising the power-plant, is placed at the left-hand side of the chassis, forward, and is carried parallel with the frame on two transverse members. These cross pieces also serve to carry two bearings which support a horizontal shaft on which the sliding friction wheel is mounted. The flywheel of the motor also serves as the friction disk. Drive is by propeller shaft to a live type of rear axle, which also embodies the differential. As the car is intended for low speeds, the gear ratio of the drive at the rear axle is 6 to 1, which, with the speed changes available in the friction transmission, permits of driving it at anything from half a mile an hour up to the maximum, which will probably not exceed 15 miles an hour.

Randolph and Lambert. The Randolph and Lambert vehicles also employ a friction type of transmission designed on the same general lines. That of the Randolph 1,500-pound delivery wagon is illustrated in Fig. 38, the method of sliding the transmitting wheel on the splines of the countershaft, as well as the manner of fitting it with a special friction facing, both being plainly evident. The disk, driven by the motor, which in this case is also of the twin-cylinder, horizontal type placed transversely across the forward end of the chassis, is also apparent. Final drive is by double side chains, according to standard practice on such vehicles. The friction type of transmission on the delivery wagons of this size has lately been discontinued, a gear drive being substituted. The same makers build a slightly larger vehicle with 2,000-pound capacity in either the friction or gear drive. The friction transmission does not lend itself to heavier vehicles and has seldom been employed on anything much larger than a 1-ton or 1½-ton wagon.

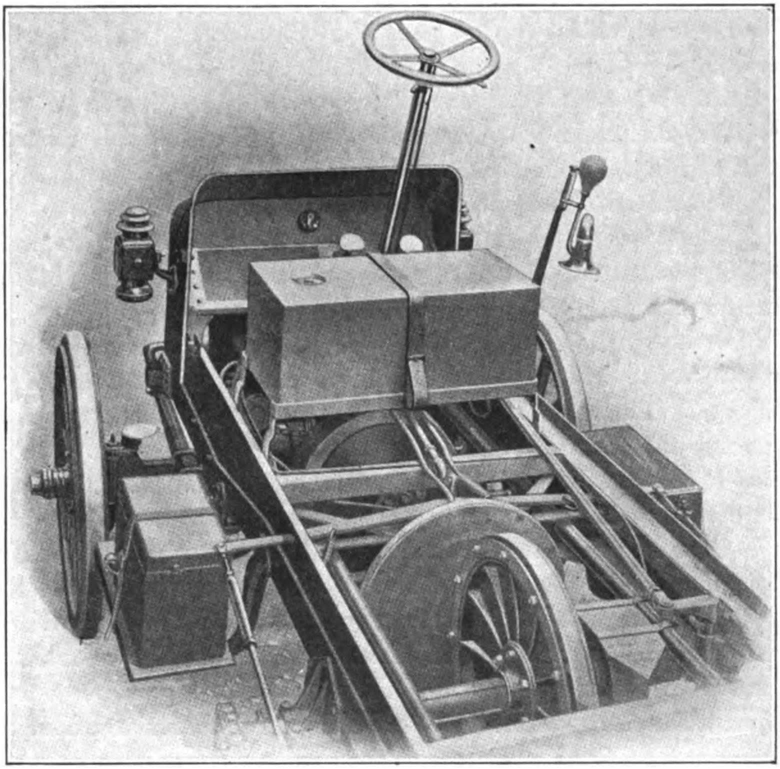


Fig. 38. Randolph Delivery Chassis Showing Friction Drive.

Friction Drive. The friction type of transmission is not generally regarded with favor by engineers, as is shown by the comparatively small number of vehicles in which it is employed. As already mentioned, this type seldom exceeds one ton in capacity, but in this rôle the friction transmission appears to bear out to a very large extent the promise of its very favorable theory. The area of actual contact between the disk and the power transmitting wheel is little more than a short line, and it would accordingly not seem to be capable of transmitting a great deal of power—particularly the effort due to starting a load on a grade or out of a mud hole—but the fact that the Cartercar vehicles have shown themselves capable of ascending grades as steep as 50 per cent, and of being stopped and restarted on such a terrific incline, would appear to dispose of this effectively. In actual service, grades as bad as 20 per cent are very rarely encountered, as a 15 per cent grade represents an exceedingly steep incline. The success of the friction-driven cars now on the market makes it apparent that this type is to be reckoned with as a factor, its low cost and absolute simplicity making it of great importance where the unskilled driver is concerned.

Most of the vehicles thus far described, with such exceptions as the Randolph and possibly one or two others, are really nothing more than pleasure car chassis with a delivery body mounted on them, but as they have been designed with a view to simplicity of construction and economy of operation, they have proven effective in both rôles. Doubtless the day is not far distant, when, with the aid of readily interchangeable bodies, the small merchant will find it profitable to use his car for both business and pleasure, by simply substituting a touring body in the evening or on Sundays and holidays. This was proposed in England several years ago, and a system of interchangeable bodies, permitting of a change from one to the other in half an hour or less, was devised to make it feasible. There appears to be no reason why the use of the machine in this double capacity should not be found entirely practical.

Special Types. For the hard and unremitting service called for by department stores and other large business houses, it is naturally quite as much of an advantage to have a vehicle specially designed for delivery purposes, as is the case with the heavier trucks. Such cars are run constantly and are, for a large part of the time, loaded to their rated capacity. It is nothing unusual for them to average 10 to 14 hours a day, practically every working day of the year that they are in use, and service of this nature does not allow for a great deal more idle time than is actually necessary for the daily washing and overhauling required to keep them up to a high standard of efficiency.

Autocar. The Autocar open-body delivery wagon, Fig. 39, affords an excellent example of a vehicle designed especially for the most severe business conditions. The motor is of the two-cylinder, horizontal, opposed, four-cycle type, the cylinder dimensions being 4¾-inch bore by 4½-inch stroke, and it is rated at 18 horse-power, according to the standard set by the Association of Licensed Automobile Manufacturers (A. L. A. M.) controlling the Selden patent. The crank shaft is mounted on imported annular ball bearings which not only add greatly to the efficiency of the motor as a whole, but do away with the attention necessary to adjust plain bearings. This construction, which is far more expensive than plain bearings, also reduces the number of parts which are subject to damage should the driver neglect to provide sufficient oil, the lubrication system otherwise being entirely automatic. Two flywheels are carried on the crank shaft, the forward one having its blades cast staggered so as to set up a strong current of air, thus eliminating the necessity of a belt- or gear-driven fan, while the rear flywheel carries the clutch. The importance of providing ample weight in the balance wheel is something to which insufficient attention has been devoted in the past, its influence upon the starting ability and smooth-running qualities of the vehicle being extremely marked, especially where a two-cylinder motor is employed. Both flywheels on the Autocar motor are counterweighted, and this, supplemented by a careful balance of all the reciprocating parts, makes an extremely smooth

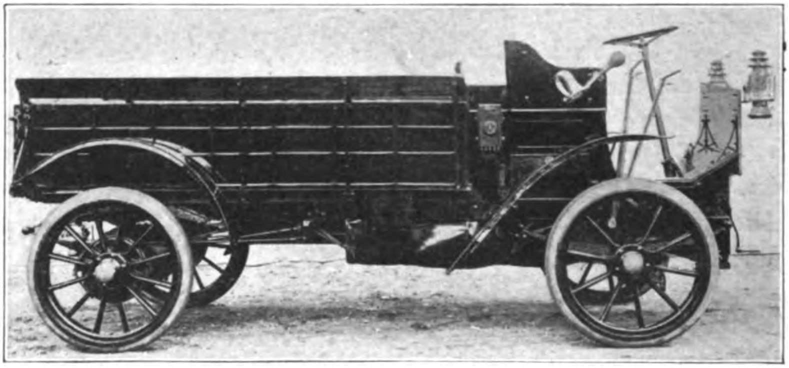
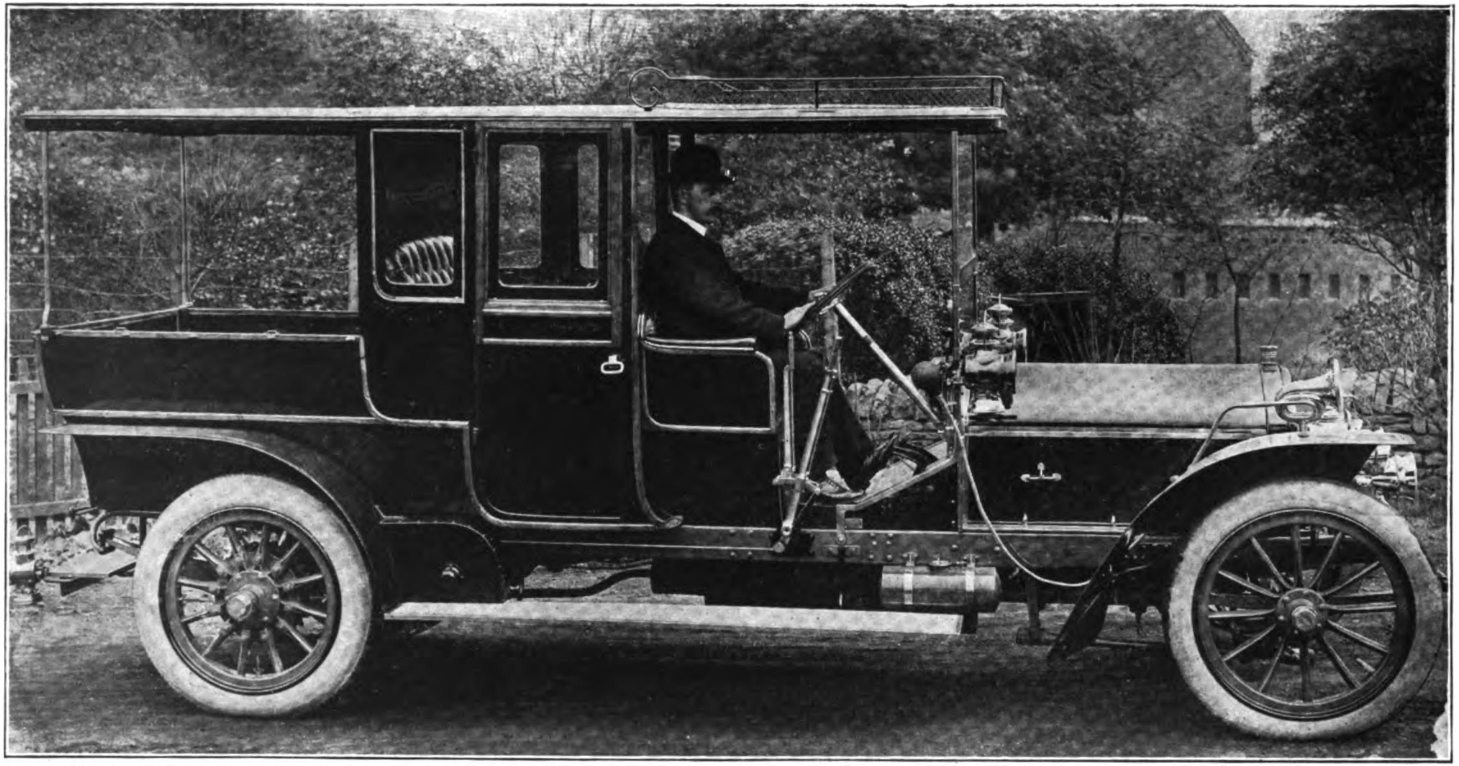


Fig. 39. Autocar Open Body Delivery Wagon.



COMBINATION PLEASURE AND BAGGAGE CAR FOR EXTENDED COUNTRY TOURING
Note carrying space on top and large rear compartment under extended cover.

and quiet-running motor with unusual starting and grade climbing ability for its size.

The crank case is split horizontally into two sections, the lower half carrying the cylinders, crank shaft, cam shaft, and water pump, while the upper half carries the push rod guides, the magneto, the oiler, and a gear for driving the water pump. The magneto and oiler are both driven through bevel gears and short shafts, reducing the possibility of failure in these two highly important essentials—ignition and lubrication—to a minimum. This upper section of the crank case is readily removable, carrying its parts with it and thus giving access to the crank-pin bearings without the necessity of dismantling the motor. A Bosch magneto is employed with a fixed firing point, thus taking this element of control out of the hands of the driver. Lubrication is by a force-feed oiler delivering oil through a sight feed to the crank case, from which the pistons, crank pins, and main bearings are lubricated by splash. Both the magneto and the lubricator are simply attached to the crank case by wing nuts so as to be removable without the aid of tools. A hydraulic speed regulator connected in the circulation of the cooling water, controls a throttle placed in the intake manifold between the carbureter and the cylinders, limiting the speed of the motor to 1,400 r. p. m. and that of the vehicle to 18 miles to 20 miles per hour.

A patented floating ring clutch that has been developed on the same make of pleasure cars and used for a number of years, constitutes the first step in the transmission. It consists of a bronze floating ring, lined with cork inserts on its inner face, and mounted on four keys on the inside of the rim of the rear flywheel, thus rotating with the latter. Two cast-iron rings, adapted to clamp the bronze ring when the clutch is engaged, are mounted on the clutch shaft, which extends into the transmission case. Engagement is accomplished by a sliding trunnion and four toggle links, the motion of which is checked by a dashpot and plunger. This insures gradual automatic action, entirely free from jerk regardless of the care exercised by the driver. The addition of small springs to the floating ring eliminates all noise whether the clutch be engaged or not, while the arrangement is such that adjustments can be easily and readily made.

The transmission housing is all one piece, except its cover plate, and it has been so designed that all the shafts and gears may be removed without disturbing the housing itself. The shafts are large and are carried on adjustable roller-bearings, while the gears have broad faces and heavy teeth. Three speeds forward and one reverse are provided, lubrication being obtained by covering the shafts and gears with a bath of semi-fluid oil.

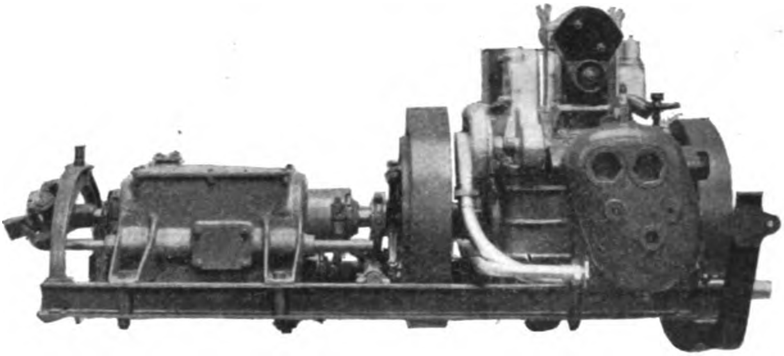


Fig. 40. Autocar Engine and Transmissiom Mounted on Separate Sub-Frame.

Both front and rear axles have been designed especially to meet the requirements of the heavy service imposed upon them in carrying the load on solid rubber tires. The front axle is of the tubular type, with extra heavy yokes for the steering spindles, which are made integral with the spring saddles. Adjustable roller-bearings are

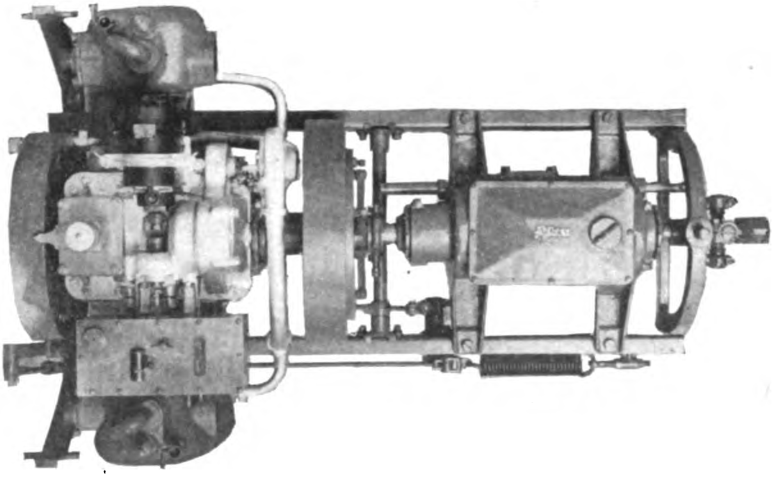


Fig. 41. Autocar Engine and Transmission—Plan View.

employed in the wheel hubs. The rear axle is of the full floating type with a double gear reduction. A bevel pinion at the end of the propeller shaft meshes with a large bevel gear on a short transverse shaft, from which the drive is transmitted to the differential case by means of a pair of substantial spur gears. The bevel pinion shaft and the jack shaft both run on adjustable roller bearings.

One of the chief features of advantage of the Autocar delivery wagon is the mounting of the complete motor and transmission, barring the rear axle, on an independent subframe, as shown in Fig. 40 and Fig. 41. In the illustration of the complete chassis, Fig. 42, every part of the power plant is seen to be accessible by lifting the bonnet, while the complete unit, as shown separately, may be removed from the chassis and replaced by another. The plan view of the chassis, Fig. 43, shows the relative location of all the essential parts, including the gasoline tank which is placed transversely on the main frame directly under the driver's seat. The frame is of pressed steel, perfectly rectangular and heavily reinforced. Two sets of brakes act on drums attached to the driving wheels, while the suspension consists of double-elliptic springs in the rear and semi-elliptic springs placed forward directly under the motor.

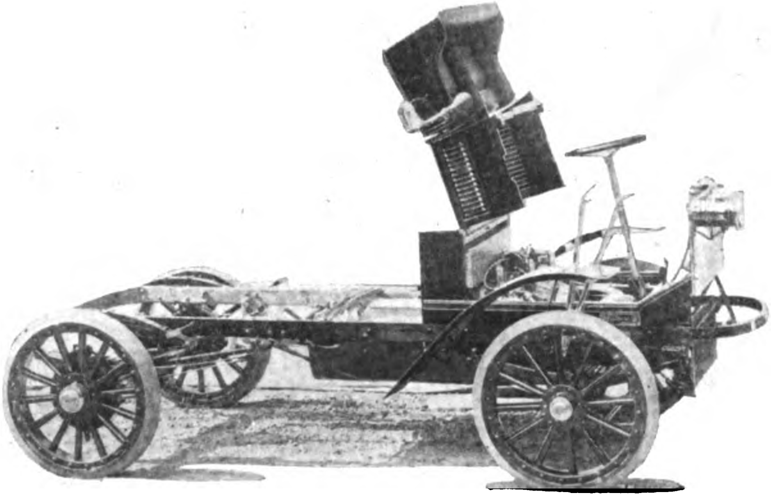


Fig. 42. Autocar Complete Chassis.

Grabowsky. The Grabowsky power wagon is another specially designed type having similarly advantageous features of accessibility and interchangeability, the entire power plant and transmission being an independent unit which is designed to slide on rails on the chassis frame, so as to be readily installed or removed. The simplicity of this operation may be judged from the illustration, Fig. 44, which clearly shows the channel members upon which the motor and trans-

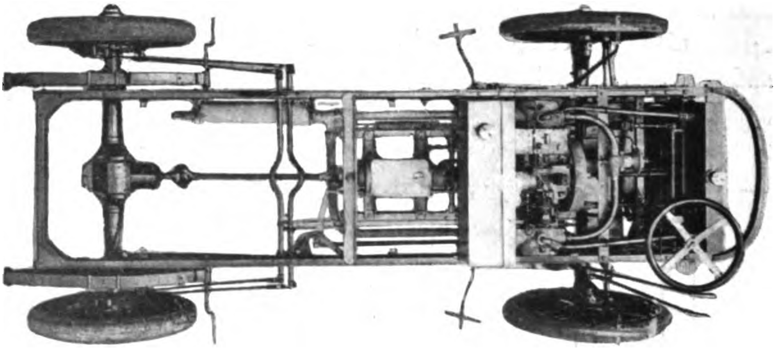


Fig. 43. Autocar Complete Chassis—Plan View.

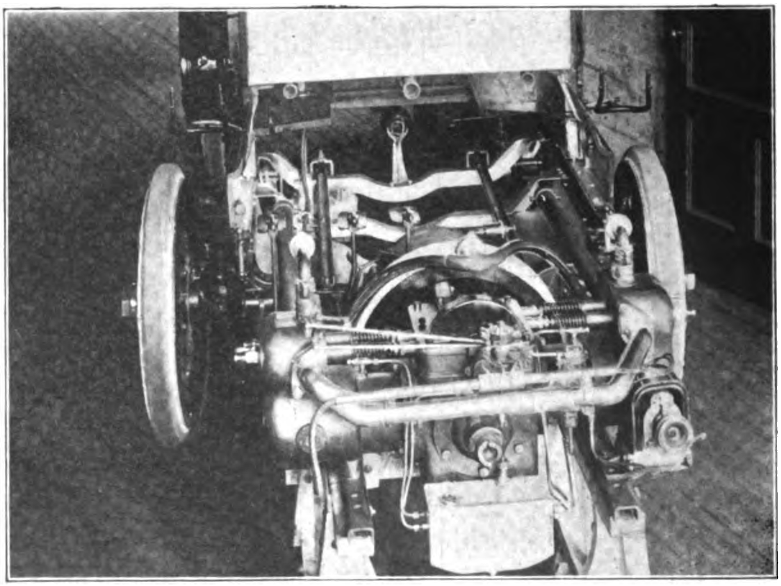


Fig. 44. Grabowsky Power Wagon, Showing Sliding Mounting for Power Plant.

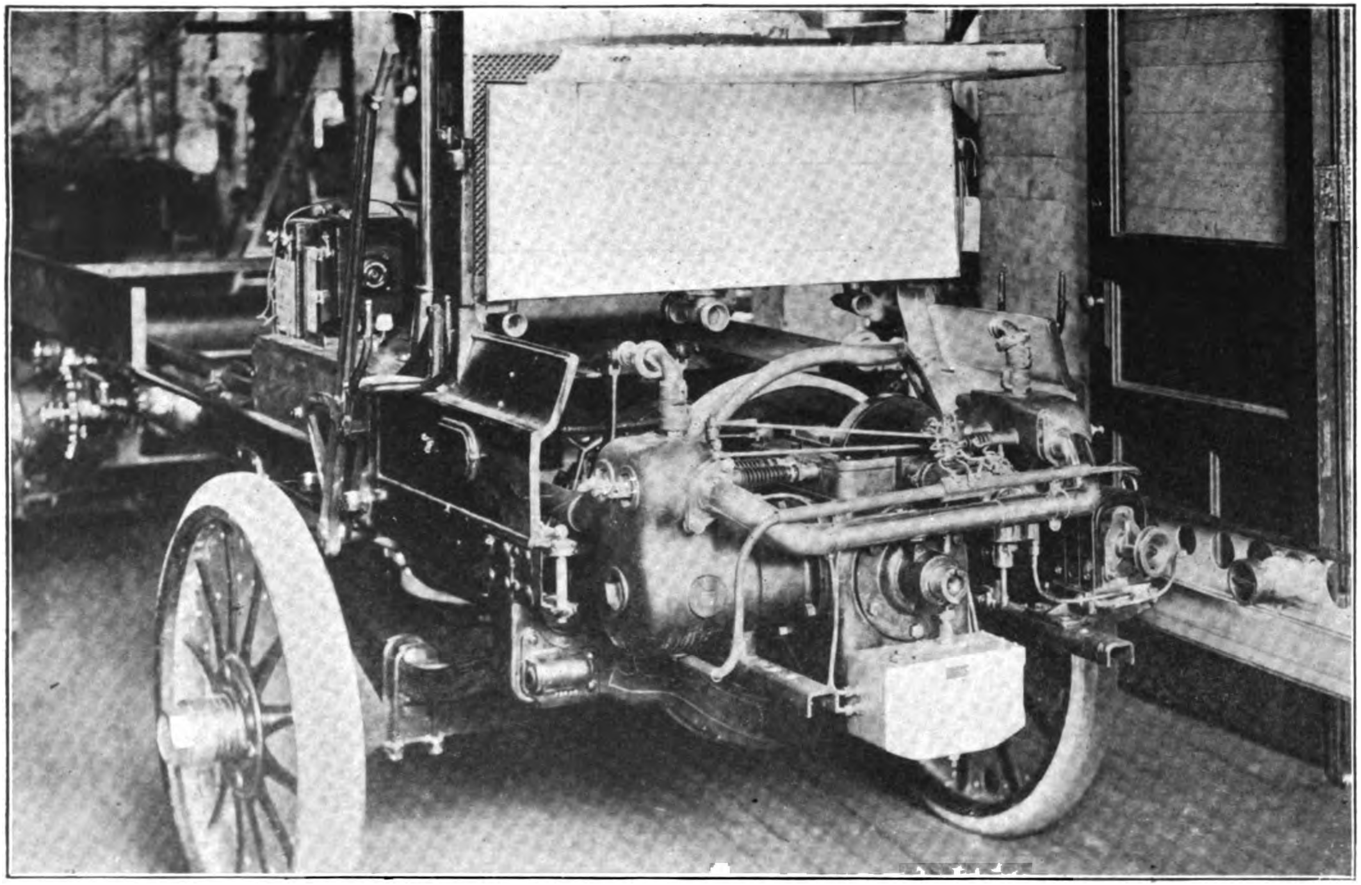


Fig. 45. Grabowsky Power Wagon with Interchangeable Power Plant—Side View.

mission gear are mounted, as well as the rails of similar section placed in an inverted position on the chassis, on which they are designed to slide. By means of the horse mounted on casters and shown in the foreground, the motor and its accompanying essentials may be slid off the chassis and replaced by another in a very short time. This is a great advantage to any delivery system employing a number of vehicles, as with an extra equipment of one complete power plant for every eight or ten cars in service, it is seldom, if ever, necessary to retire a machine from service to make repairs to the motor or transmission, as the extra unit may be temporarily installed in any one of the cars needing attention of this nature. This is on the same principle as the keeping of three horses to insure the steady service of a single two-horse wagon, six for two team wagons, and so on; except that the percentage of extra motive power necessary in the case of horse-drawn vehicles is much greater than with power wagons. The Grabowsky car shown is much heavier than the delivery types previously illustrated—in fact, it is a truck chassis, but is shown in this connection following the Autocar as a further example of a special design involving much the same principles.

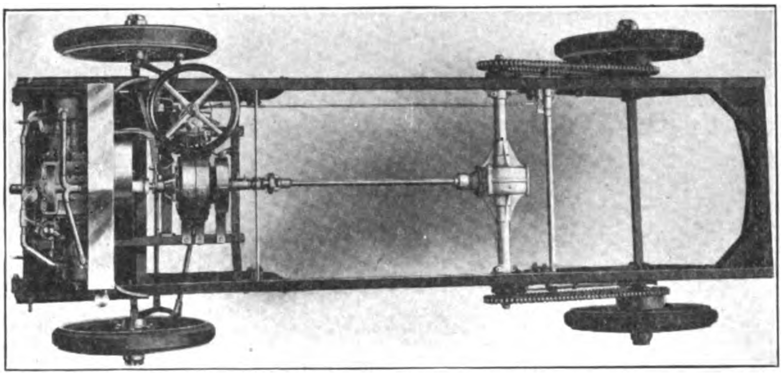


Fig. 46. Grabowsky Chassis Showing Simple Construction.

Fig. 45 serves to illustrate the ready accessibility of the various essentials of the motor by merely lifting the short hood. It may be noticed in this case that the radiator is carried above the motor. The force-feed lubricator will be seen forward just under the end of the crank shaft, while the direct-current generator for supplying the ignition current is bolted to the right-hand rail of the sliding motor sopport; the ignition timer is mounted vertically, directly over the crank shaft. The valves and their operating mechanism, the spark plugs, carbureter, and electrical and water connections are all within easy reach, most of them being mounted directly on top of the motor. Fig. 46 illustrates the great simplicity of the chassis as a whole. The drive from the planetary gearset, which is shown in part section in Fig. 47, is by shaft to the differential, mounted at the center of the countershaft near the rear. From this, the drive to the rear wheels is taken by side chains in the conventional manner. Internal expanding brakes are designed to act upon the drums which also carry the driving sprockets.

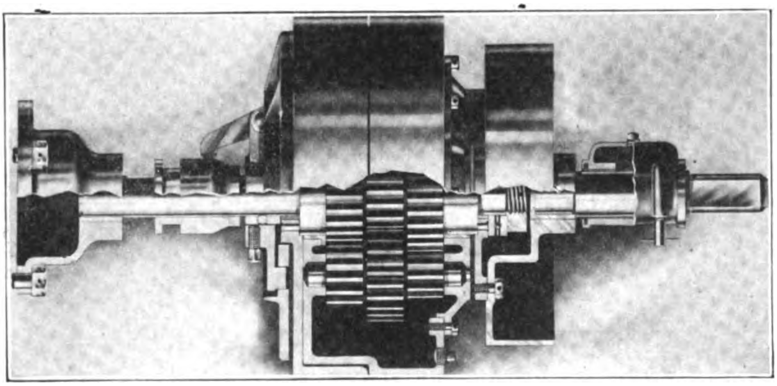


Fig. 47. Planetary Gearset Shown in Part Section.

Rapid. The Rapid cars, while specially designed in many forms for commercial service, and in which they have proven unusually successful, are characterized more by features of design that have been conventionalized in the two-cylinder pleasure car. Like the Autocar and the Grabowsky, the Rapid one-ton chassis is equipped with a two-cylinder motor of the same general type, the cylinders of which measure 5 inch by 5 inch, giving it a rating of 24 horse-power. It is placed parallel with the frame and under the body, the crank shaft carrying a two-speed planetary gearset through which the power is transmitted by a single chain drive to a countershaft, from which it is taken by means of side chains to the rear wheels in the usual way. While placed under the body, the motor is readily accessible from the side of the car, due to the somewhat greater height of the frame. The radiator is carried forward and serves as a dash, while the suspension consists of a half-platform unit composed of three semi-elliptic springs in the rear, and two straight semi-elliptic springs forward. Solid axles of 1¾-inch square section are employed, and it will be noted from this and other details of the construction that the vehicle is unusually subtsantial for its size so that its rating of one-ton capacity is merely nominal. The wheels run on Timken roller bearings and may be either of the usual artillery type or what is known as an *indestructible* wheel, made of heavy, stamped sheet steel, which not only has the advantage of great strength but is easier to keep clean than the ordinary spoked type. Internal-expanding hub brakes are employed on the rear wheels and are operated by a hand lever, and as is usual with a planetary gearset, the reverse may be employed as a transmission brake. The wheels are 32 inches in diameter and are fitted with 3½-inch solid-rubber, endless tires. By increasing the dimensions of the chassis throughout, and equipping it with a 5¼-inch by 5-inch motor, rated at 30 horse-power, it is listed as a 1½-ton to 2-ton car with a number of different types of bodies. One of the Rapid cars has the distinction of being the only commercial vehicle to have climbed to the summit of Pike's Peak. A chassis of the one-ton Rapid delivery wagon is shown in Fig. 48.

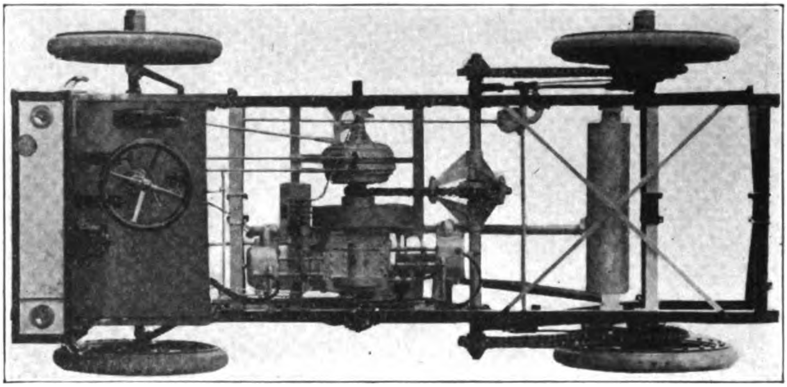


Fig. 48. Chassis of Rapid Delivery Wagon.

Types with Two-Cycle Motor. Owing to its great simplicity and lack of small parts, the two-cycle type of motor would certainly appear to hold great promise for the commercial field. It is far cheaper to build than the four-cycle type, as, with the exception of the crank shaft, connecting rods, and bearings, a two-cycle motor is composed wholly of iron castings. While not quite as economical in operation as the four-cycle where fuel consumption is concerned, the difference is hardly of sufficient moment to have an important bearing, and may be compensated for, to a large extent, by the lesser number of cylinders required, owing to the more frequent impulses. Its entire absence of valves and the numerous small parts which their operation involves makes it a particularly advantageous type to place in the hands of the ordinary driver, as, outside of the carbureter and ignition, there is absolutely nothing in the way of adjustments that the driver can tinker with. Owing to the fact that the four-cycle motor had none of the short-comings of the two, the latter was never considered seriously in the early days and almost entire attention was devoted to the development of the former, and, except for the efforts of a few pioneers with the courage of their convictions, it has not had an opportunity to demonstrate of what it is capable, either in the commercial or the pleasure-car field.

There are a few makers building two-cycle commercial cars—the whole field, in fact, both pleasure and commercial, can be accounted for on the fingers of one hand. Consequently, the two-cycle motor is still in an unsettled state—it has not yet reached that stage in its progress where it can be regarded as having been placed on a standard basis, as practically every maker is building a motor with special features of his own and no two are exactly alike, while many differ radically. But the promise it holds of future development may be gauged from its performance for many years past in the marine field, as there are thousands of small two-cycle motors in use in dories, oyster boats, and fishing boats that are put to the hardest class of business service day after day and in all kinds of weather. The two-cycle motor is also employed on a very large and constantly increasing number of motor boats for pleasure use. While marine service demands the sturdiest of construction, the speed requirements are low, the ordinary two-cycle marine motor being designed to develop its power at a normal r. p. m. rate seldom exceeding 600 turns per minute This naturally involves a weight per horse-power that is prohibitive for automobile use, the usual

6- to 8-horse-power, two-cycle, marine motor weighing quite as much or more than a 30-horse-power, four-cycle, automobile type. The reason for this will be apparent upon a consideration of the reference to the flexibility of the motor and its power output as influenced by its speed, Page 56. Weight is naturally not as objectionable in a boat as on a vehicle which must transport itself and its load on rubber tires. No little difficulty was experienced at the outset in the attempt to improve the two-cycle motor by increasing its speed in order to cut down its weight per horse-power, and the action of the motors under experiment was so erratic and unsatisfactory, particularly where an increase in their power output at the higher speeds was concerned, that many of the investigators gave up the task and went back to the four-cycle type. It is almost beyond the power of the human mind to grasp the rapidity of the sequence with which the different functions take place in a four-cycle motor when running at speeds which were thought utterly impossible twenty years ago, but which are now common. When turning over at 1,800 r. p. m., as many small motors do, they are making 30 revolutions per second. This means that 120 distinct operations must be gone through every second, *i. e.*, drawing in of the charge, compressing, firing, and exhausting it. For the accomplishment of each, there is thus allowed exactly $\frac{1}{120}$ of a second. In fact, it has never quite been figured out how the various operations can follow one another so rapidly without conflicting—just how the burning gas of one charge can be so completely expelled as not to ignite the fresh gas of the charge following it. 1,800 r. p. m. is not an extreme speed by any means, as motors have been successfully operated at a rate as high as 2,200 r. p. m. or more, though the average automobile motor is not designed to run much above 1,500 r. p. m. and the tendency is naturally to lower this rather than to increase it.

When a two-cycle motor is running at 600 r. p. m., it is carrying out as many functions as the four-cycle motor running at double that speed, so that to design a two-cycle motor capable of a speed of 1,800 r. p. m. it is necessary to so arrange its intake and exhaust that the gases may be successfully transferred with the small time allowance of $\frac{1}{240}$ of a second. This explains why the first attempts were so disappointing, as the fresh charge was either fired by its predecessor before reaching the combustion chamber, or was so small as to be productive of practically no power, this decreasing, instead of increasing, as the speed became greater. The investigations were continued, however, with the result that there are now several cars of this type that have been on the market for some time, while others are still being experimented with, and it is safe to say that the two-cycle motor will in the future become a factor of constantly increasing importance, particularly for commercial use.

Atlas. The extreme simplicity its employment makes possible is strikingly illustrated by the plan view of the Atlas delivery wagon shown in Fig. 49. As the two-cycle motor produces a power impulse for every turn of the crank shaft, instead of every other revolution, as in the four-cycle motor, it is natural to assume, that, given the same size cylinders, the power output will be exactly double, or even better, and this is a claim generally put forth by the builders of two-cycle engines. It doubtless would be true were it possible to scavenge the cylinders of the burned charge as thoroughly as is done in the four-cycle, and to inspire as large a proportion of fresh gas to the volume of the cylinder, as the latter effects. This, however, is just where the greatest difficulty in the development of the two-cycle lies. The fresh gas must be inspired and compressed on the up stroke, fired and exhausted on the next succeeding down stroke, and with the exceedingly limited time-element per function that this necessitates, it has been found practically impossible to clear the combustion chamber of the burnt gases to anything like the degree that is effected in the four-cycle with its intervening idle stroke. The result

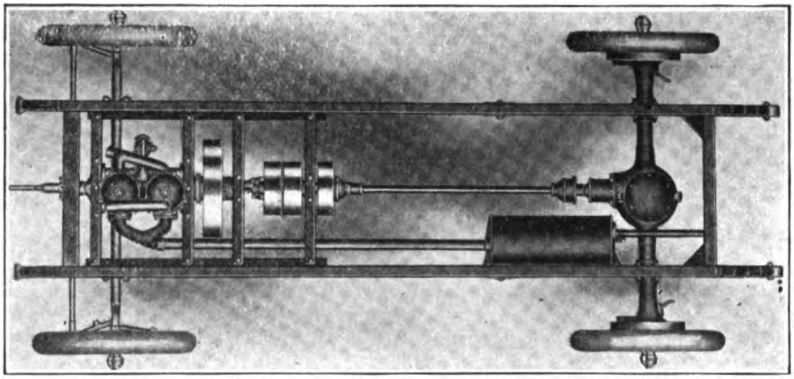


Fig. 49. Chassis of Atlas Delivery Wagon.

is that the fresh charge is always mixed with a greater or less proportion of the burnt gas already in the cylinder, with a consequent decrease in the effectiveness of each of the power impulses as compared with the four-cycle type. Owing to the rapidity with which they follow one another, however, the power output of the two-cycle cylinder is greater than that of a four of the same dimensions, particularly at the more desirable lower speeds.

It is accordingly possible to employ two or three two-cycle cylinders, in place of the usual four-cylinder, four-cycle, which not only further lowers the initial cost, but also serves to cut down maintenance charges. As the power impulses are consecutive in each cylinder during each revolution, a 180-degree crank shaft may be used in the two-cylinder and a 120-degree crank shaft in the three-cylinder, giving practically perfect mechanical as well as impulse balance, thus largely eliminating the destructive effects of vibration. This accounts for the two-cylinder motor shown on the Atlas delivery wagon chassis just referred to, the same motor also being employed on the Atlas taxicabs. The frequency of the power impulses also makes it possible to reduce the size and weight of the balance wheel necessary for a given power.

Just back of the flywheel, Fig. 49, is shown the planetary change-speed gear minus its bands and operating connections. Final drive is by propeller shaft, with a universal joint at each end, to a live rear axle. The frame is of pressed steel, of the usual channel section, with transverse members to stiffen it and support the motor and transmission gear. Suspension takes the form of three-quarter elliptic springs in the rear and semi-elliptic forward. Pneumatic tires are fitted, this, however, being optional with the purchaser. As the car is rated at 1,000-pound capacity the pneumatics may, of course, be successfully employed with advantage both to the machine and its speed. The appearance of the complete car, fitted with a closed type of delivery body, is apparent in Fig. 50, which also illustrates the control, this taking the form of pedals for the low and reverse speeds, and the brake and a short lever for the high speed, as has become practically standard practice in connection with the planetary gear. The Atlas motor is distinguished by the employment of revolving ports in the crank case, which control the admission of the charge. The latter is compressed in the crank case, as high a precompression as possible being obtained by restricting the volume of the crank case to the minimum. The pressure in the latter reaches 7 to 8 pounds to the square inch, as compared with 3 to 4 pounds in many others, so that a quick transfer of the charge is effected.

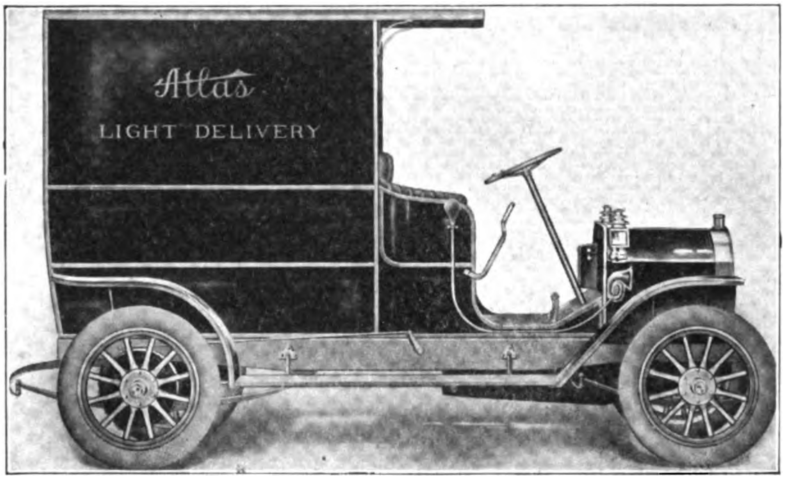


Fig. 50. Atlas Delivery Wagon.

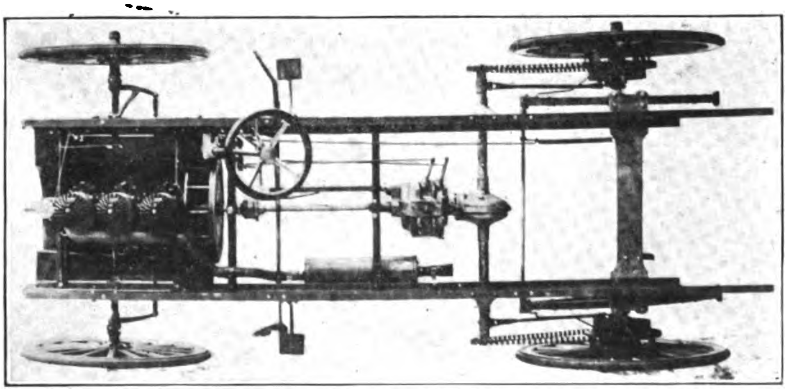


Fig. 51. Chase, Model D, Chassis.

Chase. A radically different type of two-cycle delivery wagon is illustrated by the plan view of the chassis of the Chase, Fig. 51. As will be noted, this is equipped with a three-cylinder, vertical, two-cycle motor, rated at 18 horse-power. The flywheel is made in the shape of a blower and draws a large volume of air over the cylinders, effectively cooling them. Drive is by shaft to a two-speed planetary change gear of special type, located just forward of the countershaft carrying the differential, from which the final drive to the rear wheels is taken by side chains in the usual manner, the wheels themselves being of the ordinary wagon type, fitted with small solid rubber tires. The appearance of the complete car with panel-top delivery body may be judged from Fig. 52. It has a rating of 1,500 pounds useful load capacity, and as the construction throughout is very light, its efficiency should be high. The same makers also list a two-cylinder, two-cycle, 12-horse-power delivery wagon of 500-pound capacity, the total weight of the machine with an open express type of body being 1,400 pounds.

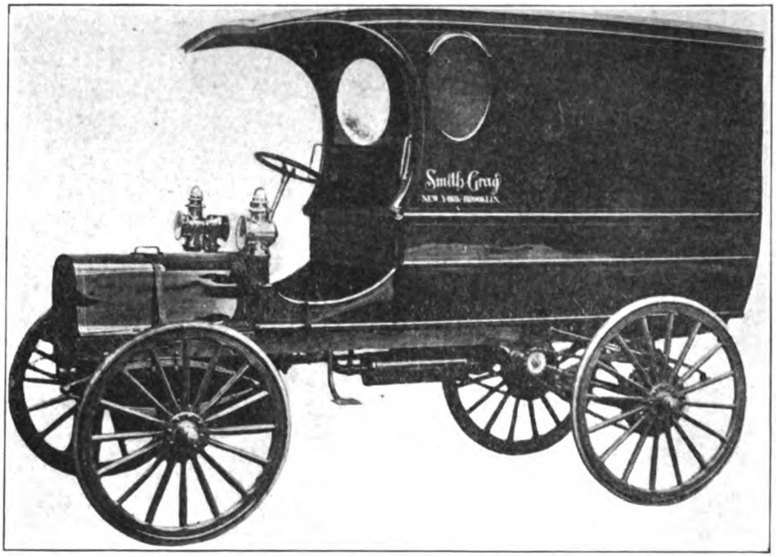


Fig. 52. Chase Delivery Wagon with Panel Top.

Templeton-Du Brie. The Templeton-Du Brie is another two-cycle commercial vehicle which has recently been placed on the market by a Detroit company of the same name. It differs totally from either of the foregoing in that it is equipped with a differential-piston type of two-cycle motor. The latter has two cylinders, and the pistons are cast with two diameters, the upper, or working half, having a 4½-inch bore and stroke, while the lower, or fuel-compressing half of the piston measures 6 inches in diameter. Fuel is admitted through automatic poppet valves from the carbureter to the annular chambers in which the larger diameter of the pistons travel, and is there precompressed to 40 pounds to the square inch. The charge thus precompressed in the annular chamber of one cylinder, is transferred through the medium of a port and an inclined passage to the combustion chamber of the next cylinder, where it is further compressed to 70 pounds to the square inch by the upward stroke of the working piston of the latter.

The transmission is a special form of planetary gear employing disk clutches and is mounted on the rear axle. The forward axle is an I-beam forging and the wheels run on ball-bearings, equalized internal-expanding brakes acting on drums on the rear wheels. The steering gear is of the worm and sector type, while the control is entirely by pedal, the various pedals controlling the low and high speed and reverse being interlocked in such a manner that only one can be engaged at a time.

Spring Design. There is a greater difference of opinion on the part of designers regarding the spring equipment than almost any other part of the chassis outside of the motor. With few exceptions, the use of semi-elliptic springs forward is universal and may be regarded as standard; it is in the rear where the greater portion of the load is carried that differences are found. Generally speaking, practice where the latter is concerned is divided between the straight semi-elliptic and the three-member or half-platform type of suspension on heavy and moderately heavy truck types, while the platform, elliptic, and half-elliptic are all found on delivery wagons.

It will be quite evident that the suspension of the average commercial wagon presents no mean problem for the engineer. The springs of the business wagon must work under widely differing conditions during the course of every day's service. Part of the time it will be traveling at a slow speed over smooth pavements with a full load, while the remainder of the time it will run light—frequently over indifferent roads—and there is always a temptation for the driver to speed, regardless of road conditions, when the vehicle is empty. The heavy static load imposed by the full body must be properly provided for, as must also the terrific dynamic stresses occasioned by bumping the empty wagon over a bad road at high speed. Between these two widely separated limits, the suspension must be such as to afford the greatest protection to the motor and other mechanisms. To illustrate the varying conditions to which the springs of a delivery wagon were subjected as well as the movement of different types of springs, the makers of the Grabowsky power wagons undertook a series of tests, the results of which are very interesting.

The vehicle selected was a Grabowsky 1-ton delivery type with a 102-inch wheel base, 56-inch tread, and 32-inch by 3½-inch solid rubber-tire equipment on all four wheels. The springs were half-elliptic forward and of the half-platform type in the rear. The front and rear side springs were 44 inches long by 2¼ inches wide and had a 5-inch opening when the car was empty. The rear cross spring was 35½ inches long by 2¼ inches wide and had a 5¾-inch opening. The weight of the car empty was 3,650 pounds, of which, after subtracting that of the axles, springs, and steel wheels, there was an actual load of 1,700 pounds on the front wheels and 950 pounds on the rear. A simple, graphic recording instrument was devised to show the extent to which the springs moved, different cards being inserted as the conditions changed.

To start with, a stretch of asphalt pavement was tried and three tests run. This pavement had the usual number of small holes or depressions, which are unavoidable, even on a well-kept road. The car was run over this pavement for some distance without any load at an average speed of 15 miles an hour. The cards showed the springs to be riding very easily with a normal motion, and with very little rebound, averaging approximately 1¼ inches above the center line and about ¾-inch below in the case of the front springs, while the rear side moved but slightly more than this and the end cross spring averaged but little more than ⅝-inch in either direction. Next, a block-paved street which had already passed its initial stage of smoothness was experimented upon and a second series of cards run off. The latter preserved the same characteristics as the first series where the compression and rebound (the former representing movement below the center line of the card and the latter above it) were concerned, but also revealed a far greater range of action, doubtless due to bad spots in the road, the compression reaching a maximum of 1⅝-inches and the rebound 2 inches. This was likewise

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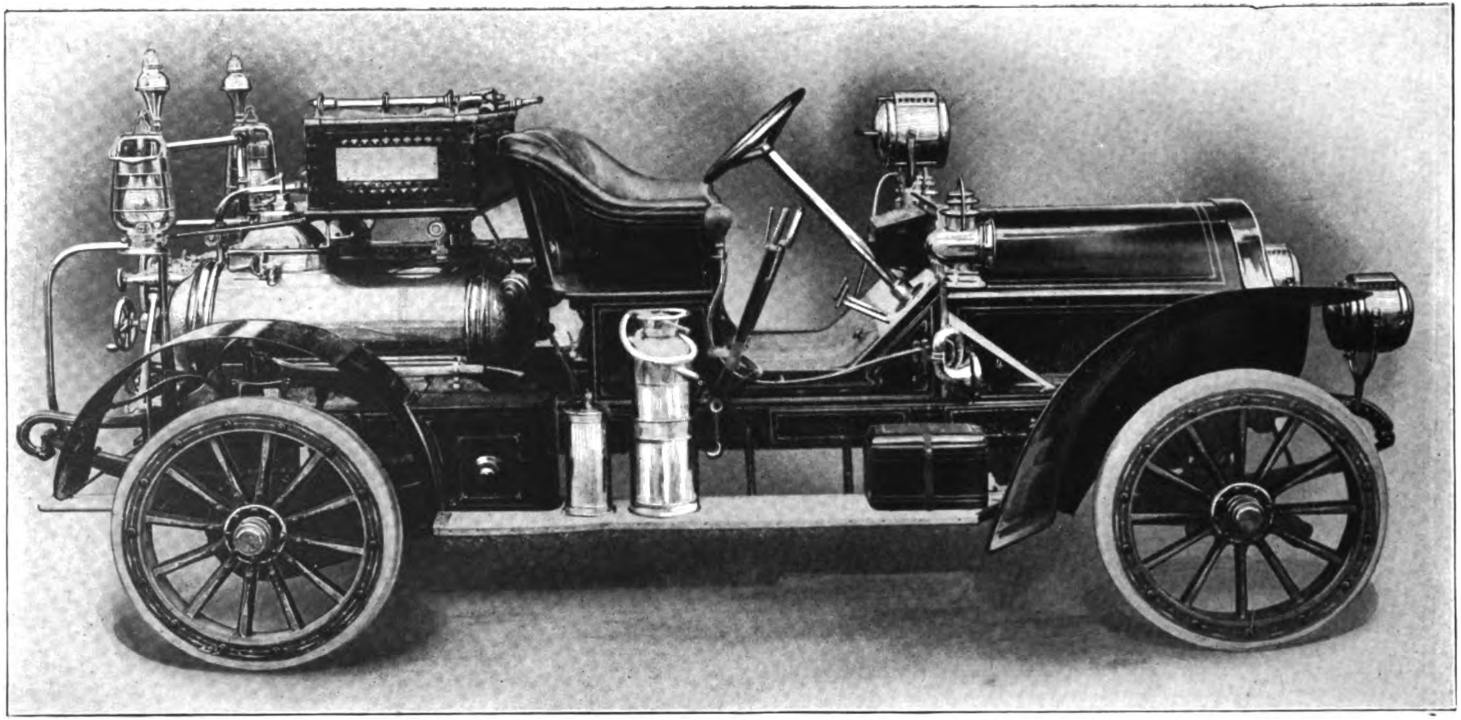


AUTOMOBILE CHEMICAL FIRE ENGINE.
Knox Automobile Company, Springfield, Mass.

true of the third series, which were taken over a stretch of very rough and uneven road, including a bad railroad crossing, the compression in this reaching 2¼ inches and the rebound 1¾ inches. The cards in question were all taken with the vehicle light.

To make the tests comprehensive, a load of 2,550 pounds was then put on the wagon and distributed as uniformly as possible. The total weight of the car and its load was then 6,200 pounds, which, after the proper deductions for the wheels, springs, and axles were made, left a net load of 2,000 pounds on the front springs, and 3,200 pounds on the rear springs. It will be noted that the load in question was 25 per cent in excess of the rated capacity of the machine. Under it, the front springs closed ⅞-inch and the rear closed 3 inches, the rear cross spring settling 2⅛ inches. With a normal load, this compression would have been correspondingly less, but the test was purposely carried out with an overload because of the frequent overloading by the owners themselves in active service. It is more or less common practice for commercial-vehicle owners to exceed the rated capacity of the machines. The road selected was even worse than that over which the wagon had been driven for the last series of empty trials. It was found that the compression and rebound retained almost exactly the same relation to each other that they had before, though the range of movement under sudden stress was naturally greater, reaching as high as 2½ inches in either direction, this being experienced as the result of dropping into a depression after crossing a railroad track. Another make of car having platform springs both front and rear was tested as a comparison. The sides of the platform were 36 inches and the rear members 37 inches in each case, the springs being 2¼ inches wide. Normally, they stood open 7 inches, closing 1¾ inches under a load of 2,000 pounds. Owing to the poor material employed and the stiff construction necessary to make it stand up, an extremely jerky and uncomfortable movement of the car was produced. The steel employed was of such poor quality that the springs soon took an excessive permanent set, and after a comparatively short period of service lost their springiness altogether.

GASOLINE TRUCKS

As is the case with the electric vehicle, there is no sharply defined line of demarcation between the gasoline delivery wagon and the gasoline-driven truck. Owing to its far greater proportion of power to weight and the fact that its radius of travel is not limited, as in the case of the electric, load carrying capacity is not as closely restricted. It is almost as economical to operate a 1,500 to 2,000-pound wagon of the gasoline type, as it is a 1,000-pound vehicle and the larger vehicle will stand up better under heavy duty. Even though the loads be such as could practically always be transported on the lighter vehicle, the heavier wagon represents a better investment in the end, despite the increased first cost, except in cases where the average load is such as to fall considerably below the normal carrying capacity of the 1,000-pound wagon. Hence, there is even less difference between the heavy gasoline delivery wagon and the light gasoline truck, than is the case between the electric of these two types. Such cars as the Rapid, Autocar, and Randolph of 1,500- to 2,000-pounds capacity are accordingly fitted by their makers with open stake, express, or closed delivery bodies, and in the case of the Rapid are also utilized as buses or sight-seeing wagons having a capacity of 12 to 16 persons.

It is in the transportation of heavy loads that the gasoline-driven vehicle shows to the greatest advantage on a ton-mile basis, as well as in speed of delivery, as its ability to travel is not hampered by power restrictions. It has been pointed out that with an increase in load-carrying capacity, not alone the traveling radius but the speed of the electric is greatly reduced, and as the radius of travel increases with a reduction in the discharge, it is accordingly not economical to attempt to run a heavy electric at more than a very moderate speed. 5-ton and 10-ton trucks driven by electric power are not capable of being driven at a speed much in excess of 4 to 6 miles an hour, and even at this low rate of travel, their radius is rather limited, while the great amount of battery necessary tends to cut down their efficiency somewhat. For this reason, electric vehicles have, in the main, been confined to the light and medium capacity types, though not a few 5-ton and some 10-ton trucks are in operation. The total number, however, is insignificant as it is difficult for them to compete on an even basis with the gasoline-driven commercial vehicle in the transportation of heavy weights. Speeds of eight miles an hour are easily attained by 10-ton trucks of the latter type, and at this rate of travel they are most economical of fuel when carrying full load. This is not their maximum speed even with full load, as they can be run as fast as 10 miles an hour, with an increase to 11 or 12 miles an hour when empty.

Air-Cooled Motors Show High Load Efficiency. Mention has already been made in connection with the description of electric delivery wagons that load efficiency, or the amount of useful weight that may be carried in proportion to the weight of the vehicle itself, increases rapidly with the size of the vehicle. This, of course, varies not alone with the make of vehicle, but also with the type, those employing air-cooled engines naturally having a great advantage in this respect. Take the Franklin 1,000-pound wagon as an example. The weight of the chassis is but 1,800 pounds, which gives it an apparent efficiency of 62.5 per cent. Naturally, the load cannot be carried on the chassis, but as the bodies employed vary so much in design and weight, the manufacturer usually lists the weight of the chassis alone. In the case just cited, the addition of an open, stake body or a closed, delivery type would add two- or three-hundred pounds, making the actual efficiency of the vehicle slightly in excess of 50 per cent. In the case of the one-ton Franklin truck, the increase in efficiency is strikingly illustrated, as the increase in the weight of the chassis itself is merely nominal, so that even with the addition of the body and in complete running order with a supply of fuel and oil, the load efficiency is close to 100 per cent. An equally favorable showing is made by the Knox trucks equipped with an air-cooled type of motor. For instance, the Knox 1,500-pound, air-cooled machine has a chassis weight of but 1,800 pounds, while the chassis of the 2,500-pound size only tips the scale at 2,100 pounds. This difference is even more accentuated in the 3-ton, or 6,000-pound truck, Fig. 53, the chassis of which weighs but 5,100 pounds. To cite further examples of relative weights which show a very favorable efficiency due to the same cause, the Knox 3,000- and 4,000-pound, air-cooled chassis may be mentioned, Fig. 54. These weigh 3,260 and 4,200 pounds respectively. It will be noted from the fact that not alone the type of motor and the style of body have a direct and important influence on this, but likewise the tire equipment, as the

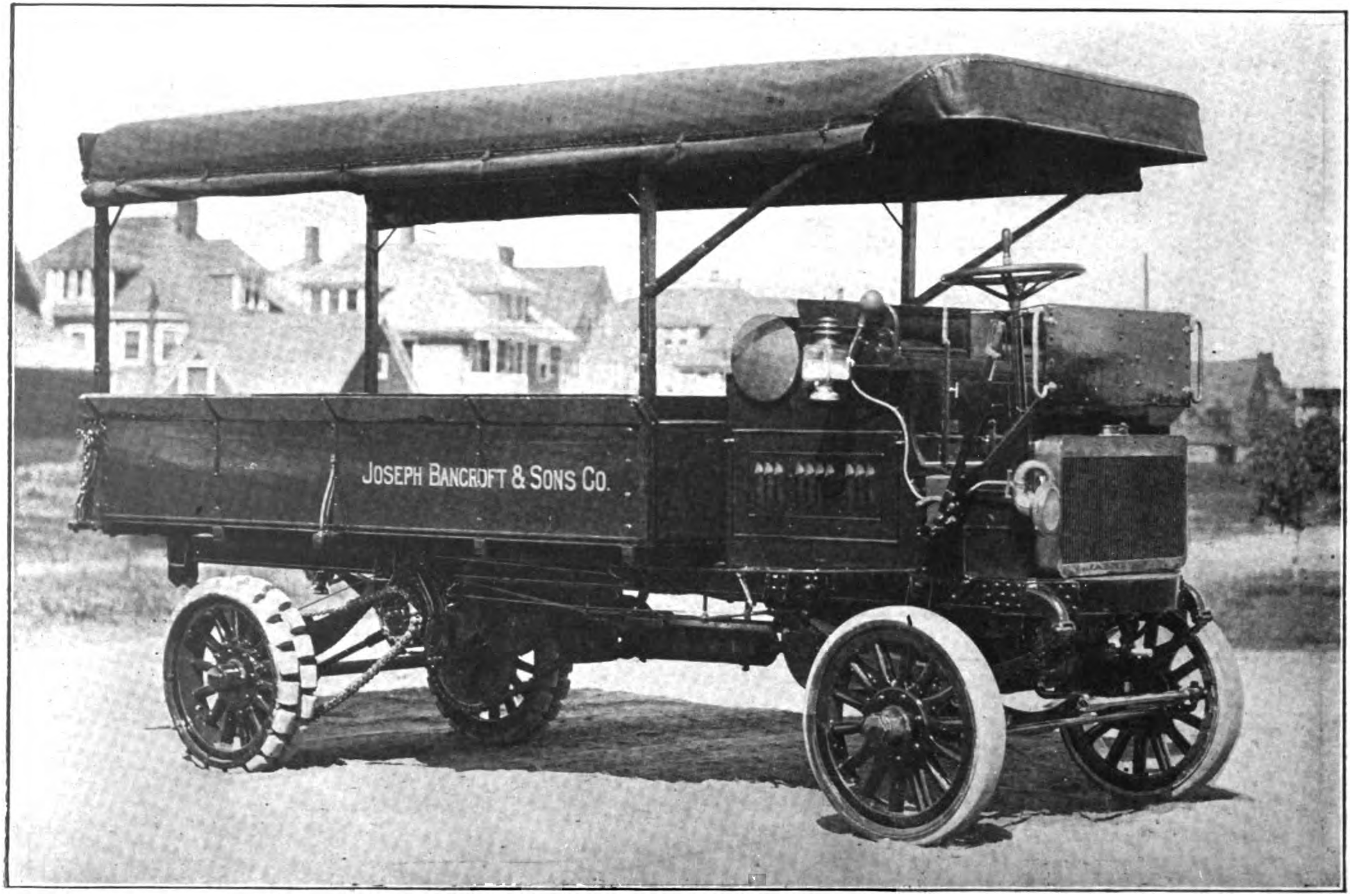


Fig. 53. Knox 6,000-Pound-Capacity Truck

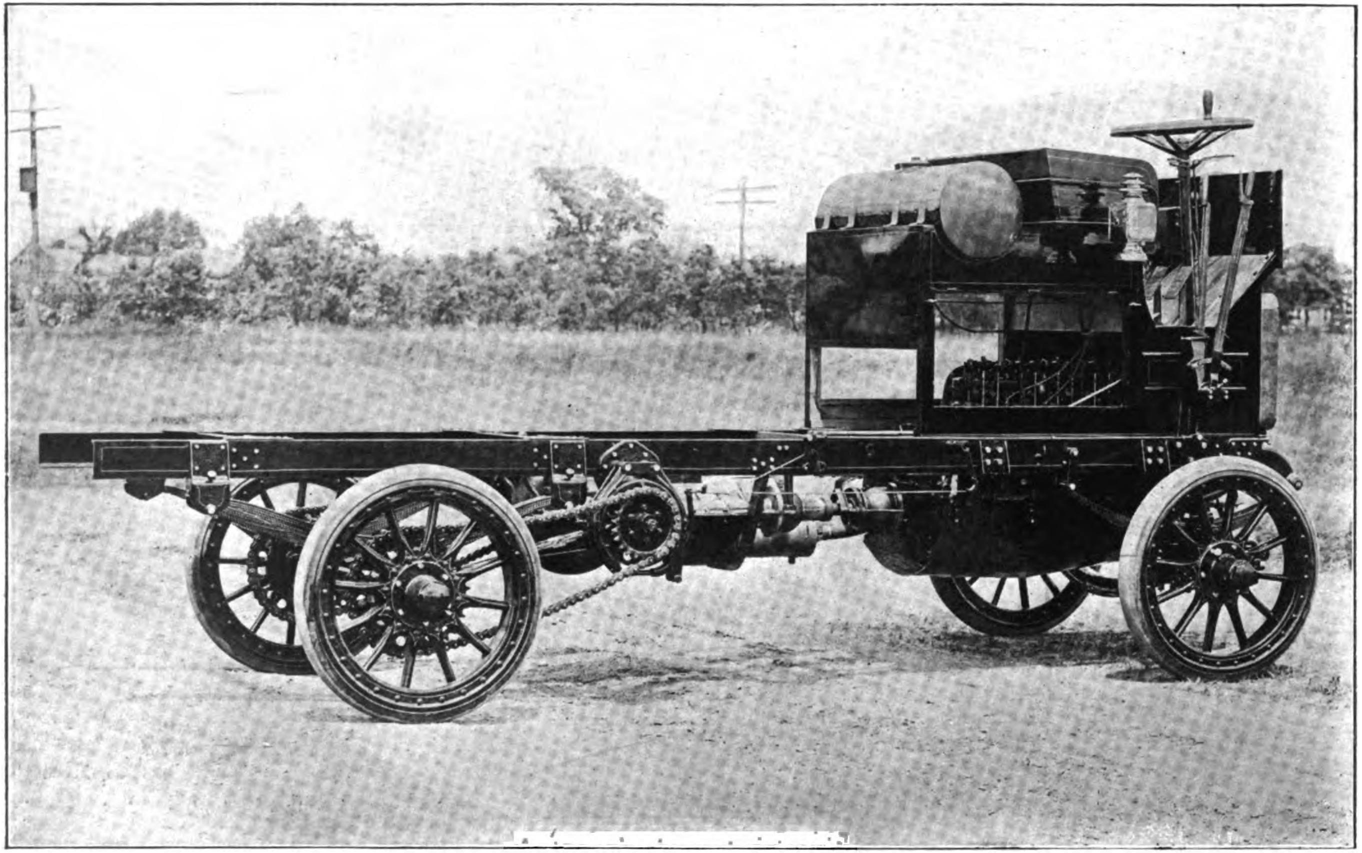


Fig. 54. Knox 4,000-Pound Chassis.

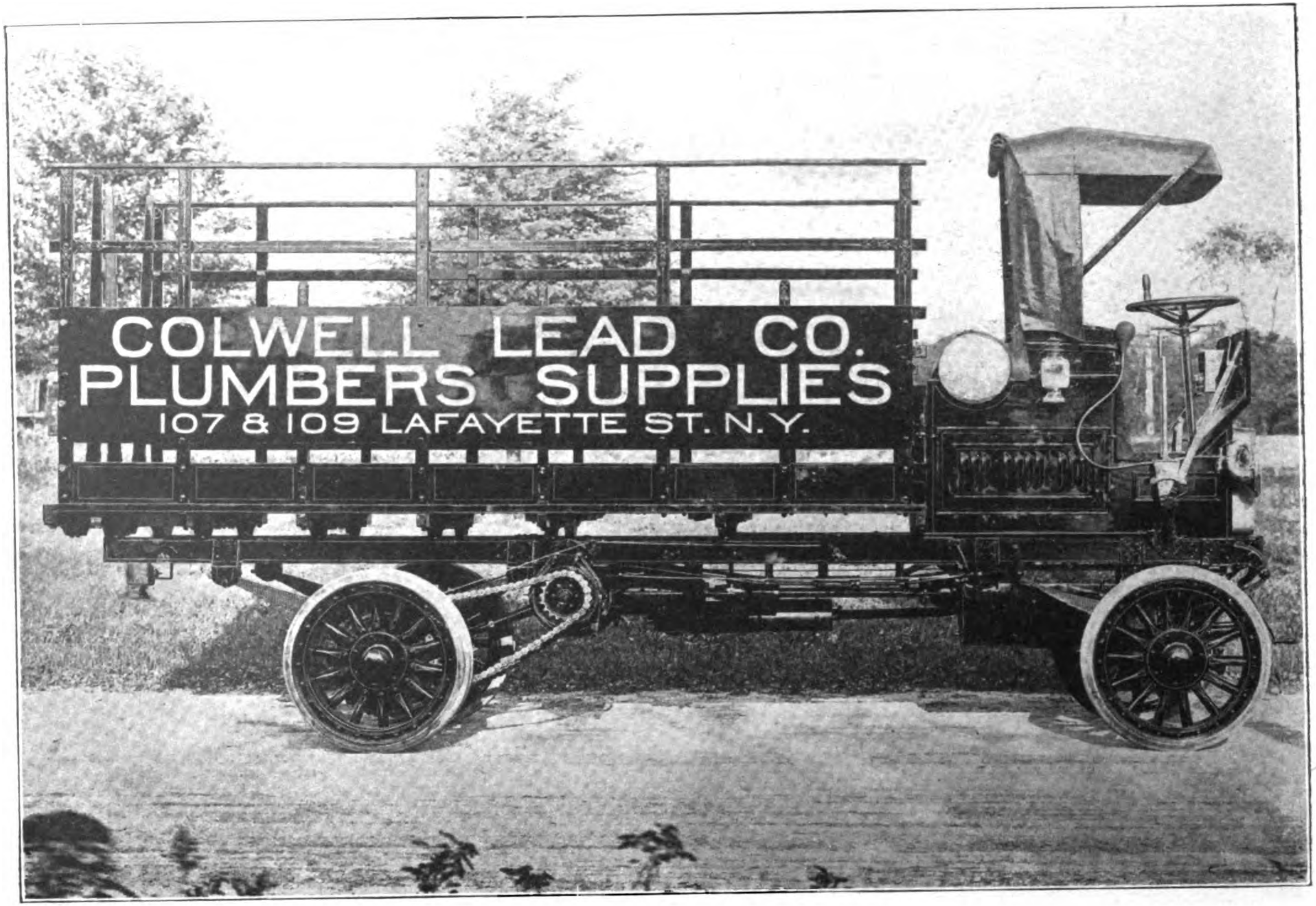


Fig. 55. Knox 4-Ton Stake Truck

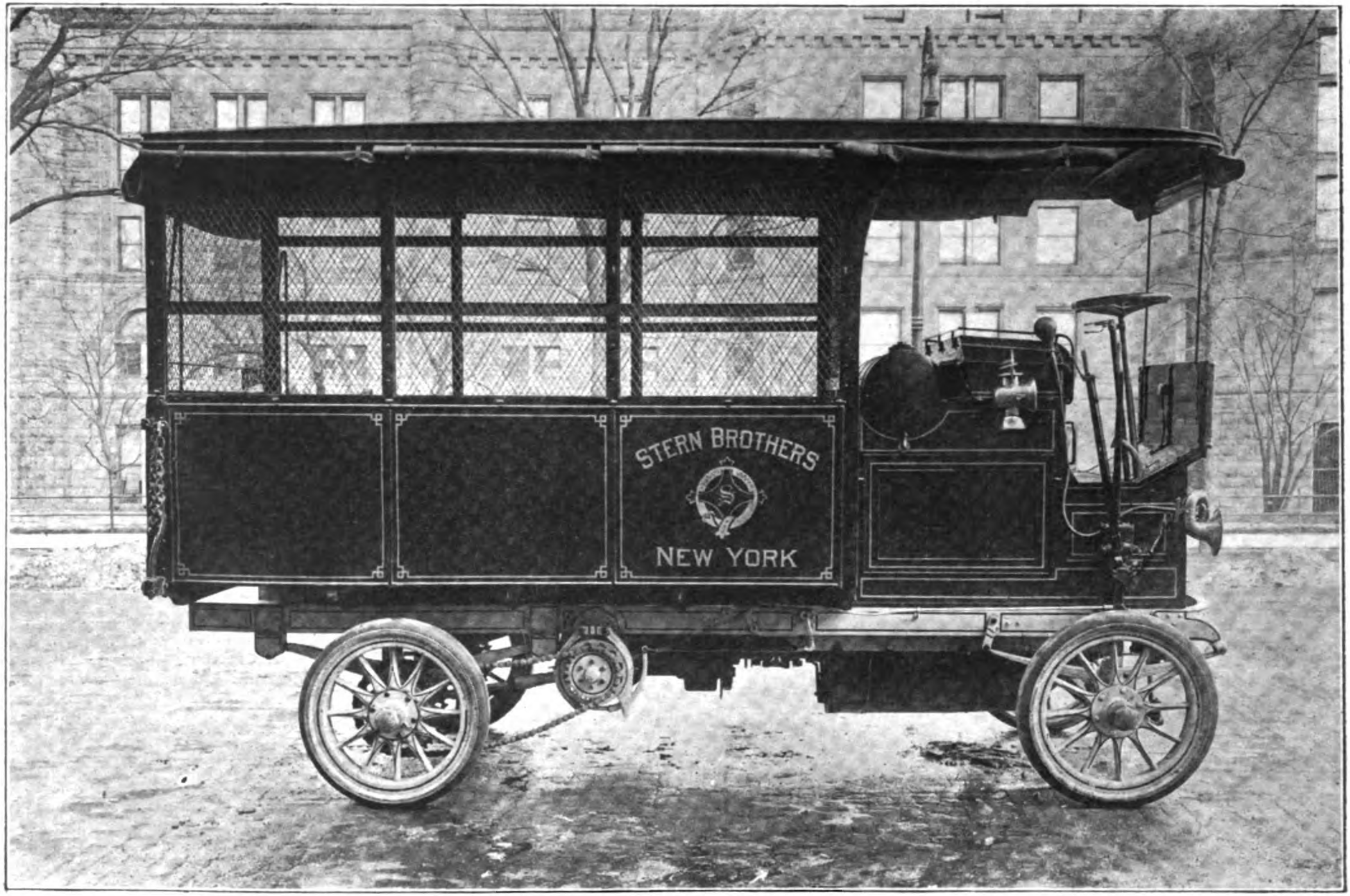


Fig. 56. Knox 2-Ton Screen-Top Var..

4,000-pound Knox air-cooled wagon has a chassis weighing but 3,600 pounds when designed for pneumatic tires, as compared with 4,200 pounds for solid rubber tires. Fig. 55 shows a Knox 4-ton truck, and Fig. 56, a 2-ton truck. Equally high efficiencies are shown by the Frayer-Miller air-cooled trucks.

Load Efficiency Increases with Size. Above the 2-ton size, it will be apparent that the load efficiency either very closely approximates 100 per cent, or actually exceeds it by a constantly increasing margin as the size of the vehicle increases, as, once a certain point is reached, additions to the weight caused by increasing the dimensions of the load-carrying space and adding to the power of the motor are disproportionately small as compared with the increase in load capacity. Thus the American Locomotive truck of 3-ton capacity has a chassis weighing but 4,500 pounds, and tips the scales at only 5,200 pounds completely fitted, or "all on"; on the other hand, the Manhattan chassis for the same nominal carrying capacity, *i. e.*, three tons, weighs 6,000 pounds. However, as no standard for rating the load-carrying capacity of gasoline trucks has ever been attempted, and one maker's 5-ton truck is sometimes no larger than the 3-ton truck of another, it is difficult to always make comparisons that will be fair on a basis of catalogue weights alone. The custom that grew up in the pleasure-car field of greatly underrating the weight has doubtless had its influence here as well, and some of the figures are probably nothing more than "catalogue weights," but under the circumstances, they represent the only data available. Another great source of difference that is practically impossible to reconcile is the extreme variation between the dimensions of the bodies which are given the same load-carrying capacity by different makers. In fact, this may well be illustrated in the product of one maker. The Knox 4,000-pound car, equipped with a 48-horse-power, water-cooled motor, and 40-inch by 6-inch pneumatic tires, tips the scale at only 4,000 pounds. This is likewise true of the same type of car of 40 horse-power and 4,000-pound load capacity equipped with 34-inch by 4- and 5-inch solid tires, and at first sight, it would seem that the pneumatic tires did not influence the result in this case. A little further investigation of the specifications, however, reveals the fact that the pneumatic-tired vehicle has a wheel base of 145 inches and is capable of speeds up to

40 miles an hour, while the solid-tired car is only 103 inches on the ground and its maximum speed is but 15 miles an hour.

To give an illustration of the increase in load efficiency with the increase in capacity, some of the larger types of Knox cars may be cited, reference to the different models of the same maker tending to produce a greater uniformity of result than where various makes are compared, owing to the many points of divergence which make comparisons difficult. Thus, the Knox 4-ton truck has a chassis weight of but 5,400 pounds; the 5-ton, 5,600 pounds; and the 7-ton, 6,500 pounds. The Manhattan 4-ton truck has a chassis weight of 6,600 pounds; the 5-ton, 7,200 pounds. Fitted with a special steel dumping body of heavy construction, the complete weight averages 10,000 pounds, thus giving it an efficiency of practically 100 per cent in this respect. While the efficiency of a passenger bus can naturally not be calculated on the same basis, it is interesting to note that the Manhattan 16-passenger bus averages 6,800 pounds, complete with body and fittings; and the 22-passenger type, 8,000 pounds. These two correspond with the 3-ton and 5-ton trucks, but the bodies naturally are heavier.

Types. The points of difference in design, construction, arrangement of the essentials, and other details are quite as diversified as in the case of the delivery wagons. So, in order to give a comprehensive idea of what will doubtless form one of the most important automobile types of the future, and which is, in fact, destined to eliminate the horse from this field almost entirely, a number of makes are described more or less at length and their differences or correspondence with others made clear.

Franklin. Both the Franklin 1,000- and 2,000-pound light trucks are really on the dividing line between the light truck and the delivery type, as either may be used for one or the other purpose, depending entirely upon the body with which it is fitted. The cars have as their motive power an air-cooled motor of a special type. In the case of the 1,000-pound wagon, it has four independently-cast cylinders of 3¾-inch bore by 4-inch stroke, and rated at 18 horsepower. Vertical flanges are placed on the outside of the cylinders, covering the entire stroke of the piston, and are surrounded by light jackets open at the top and bottom, while the entire motor is also encased in a light sheet-steel housing reaching half-way up the cylin-

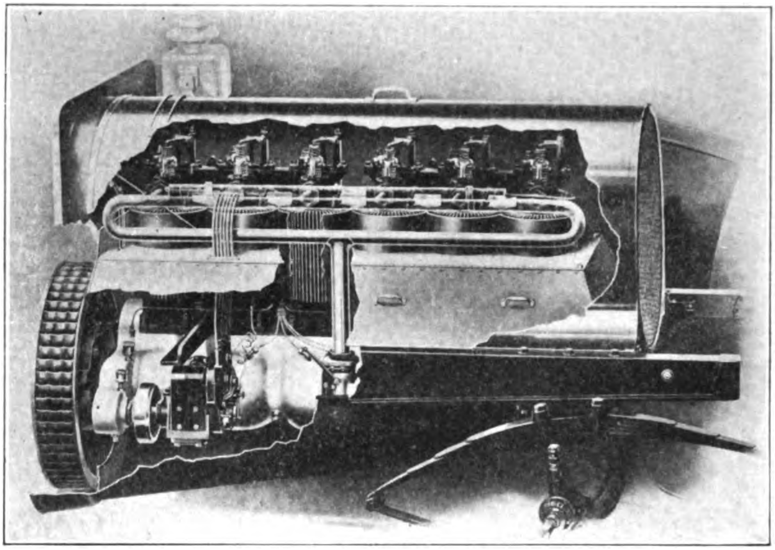


Fig. 57. Franklin 6-Cylinder, Air-Cooled Engine.

ders. This is to compel all of the air drawn in by the powerful suction fan—which also forms the flywheel—to pass down through the air jackets of the cylinders and over the cooling flanges, then through the fan and out at the rear of the car beneath the body. A

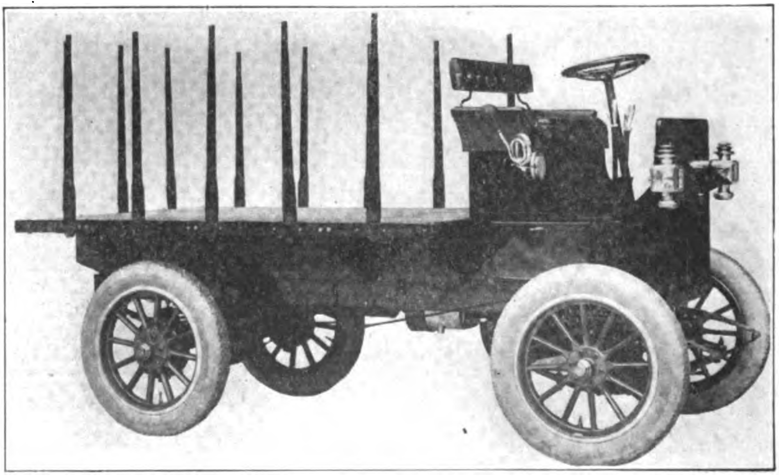


Fig. 58. Franklin Truck with Stake Platform.

clear idea of this construction may be obtained from Fig. 57, which shows a six-cylinder motor of the Franklin air-cooled type.

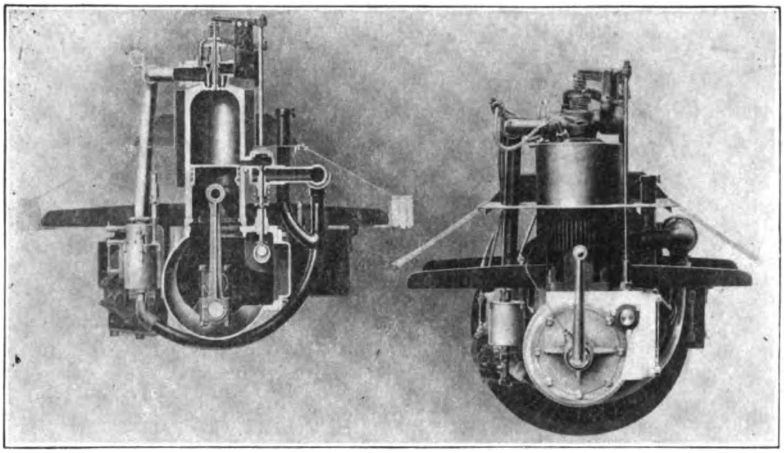


Fig. 59. Section and Front View of Franklin Engine.

In the case of the truck, a different form of bonnet is employed, for the motor is mounted directly beneath the footboard, as will be noted from Fig. 58, which illustrates the complete Franklin chassis of the

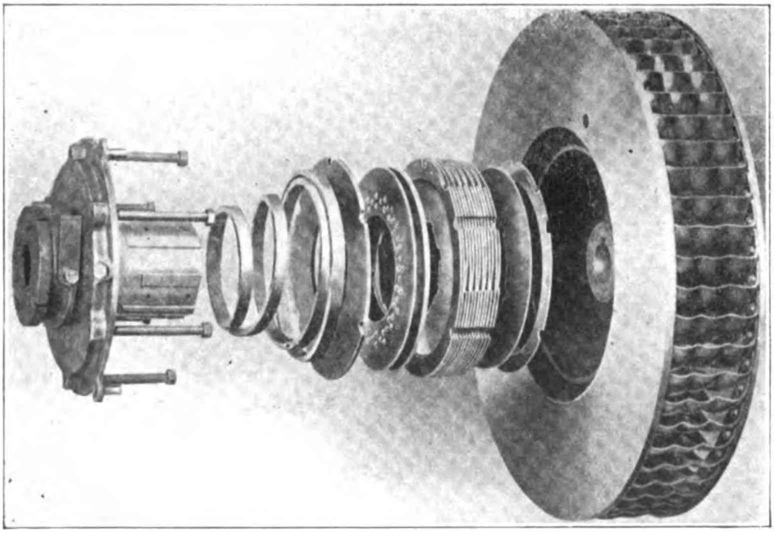


Fig. 60. Suction Flywheel and Dissected Clutch of Franklin Engine.

2,000-pound size. Further details of the motor construction are shown in Fig. 59, the sectional view of which serves to illustrate the auxiliary exhaust distinguishing the Franklin motor, while the construction of the suction-blower flywheel, and the details of the multiple disk clutch employed, are shown in Fig. 60. The same size motor is employed on the 2,000-pound as on the 1,000-pound truck, and the gear ratio on both is 6.83 to 1. In fact, their specifications throughout are practically identical, there being but 50 pounds difference in the weight. The construction throughout is the same as that of the Franklin pleasure cars, a laminated wood frame, tubular-front and rear axles being used, the latter of the semi-floating type. The springs are 40-inch, full-elliptic in front, with semi-elliptic and coil springs in the rear. A sliding gear of the progressive type, giving three forward speeds and reverse, constitutes this element of the transmission, final drive being by propeller shaft. All brakes are of the external, contracting type, one being placed in a drum on the hub of each rear wheel, and one on the transmission drive shaft. Instead of the usual bevel-gear drive, a worm and pinion are employed. The tire equipment consists of 37-inch by 5-inch Goodrich quick-detachable pneumatics on the 1,000-pound wagon, and 36-inch by 5½-inch tires of the same make and type on the larger wagon.

Knox. As practice in the commercial field is not hampered by prejudice or other unfounded bias as in the pleasure-car field, but is based purely on results figured on initial cost and expense of operation, the air-cooled motor is now much more in evidence in the business wagon than it is in the car built merely for pleasure. Thus no less than six different models of cars equipped with air-cooled motors are listed by the makers of the Knox machines, who confine themselves entirely to the water-cooled motor in pleasure-car design. These range from the single-cylinder, 1,500-pound delivery wagon, the motor dimensions of which are 5-inch bore by 8-inch stroke, rated at 8 horse-power, up to the 3-ton truck, fitted with a four-cylinder motor, having 4¾-inch by 5½-inch cylinders and rated at 36 horse-power. Between these two extremes, there is the 2,500- and 3,000-pound wagon which has a two-cylinder, 5-inch by 7-inch, 20-horse-power motor. The Knox motor is cooled by means of a large number of successive series of corrugated pins which are tapped into the outside face of the cylinder and are placed in staggered relation to one another to deflect the currents of cool air passing over them. Both the single-cylinder and two-cylinder cars are fitted with a regulation planetary two-speed gear and chain drive, while the 4,000- and 6,000-pound wagons having 36-horse-power, four-cylinder motors, have a three-speed sliding gear of the selective type, Fig. 61. While the latter naturally differ to a greater or less extent in detail from many others of the same kind, their design may be regarded as typical of those generally employed, so that the following description may be taken to cover the majority, with a few amendments, such as the employment of annular ball-bearings, instead of the roller type shown in the illustration. The main driving shaft may be seen extending forward with a flange at its right-hand end for coupling to the shaft from the clutch. Parallel with it are the operating rods which carry yokes adapted to move the gears back and forth, according to the position of the hand lever, which picks up one or the other of these short operating rods, in accordance with which side of it is moved, or, when in a sector, which slot of the latter it is in. Thus the rod and its yoke farthest away from the main driving

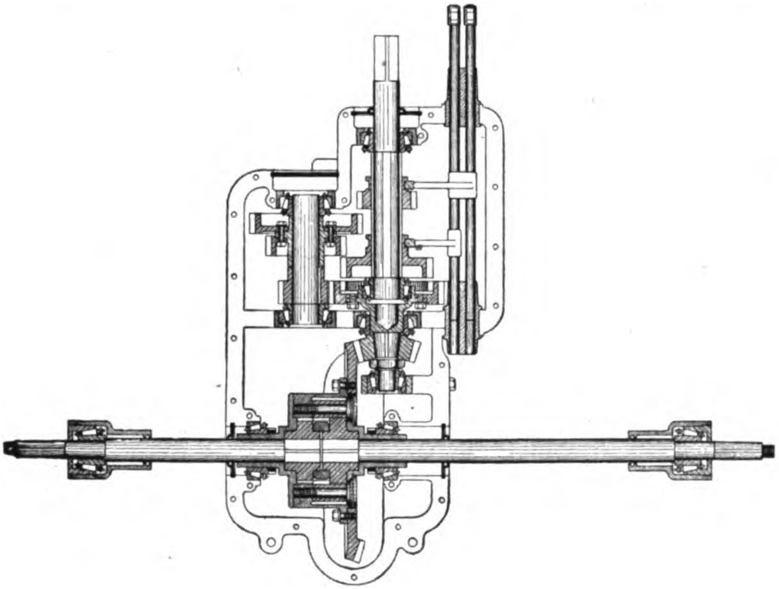


Fig. 61. Knox Three-Speed Selective Transmission.

shaft, controls the first speed forward and reverse, the last-named through an extra pinion underneath it, not plainly visible in the illustration. The inner rod controls the second and third speeds forward, and as shown, is in the second speed engagement. For the third or high speed, usually known as the *direct drive,* the two parts of the main driving shaft are locked together so that the power of the motor is then transmitted directly from the clutch to the bevel pinion and large gear without the intermission of any other reduction. This large bevel also incorporates the differential, which is mounted on the countershaft. At its outer ends, this countershaft carries sprockets of small size, driving by means of side chains to larger sprockets on the rear wheels, these constituting a further reduction in the speed between the motor and the drivers. On the high gear, the ratio is 6.75 to 1, which, at 1,500 r. p. m. of the motor, equals 222 turns of the 36-inch wheels with which the car is equipped, and is equivalent to a maximum speed of 22.6 miles per hour. The gear ratio of the second speed is 11.81 to 1, and at the same motor speed, it turns the rear wheels 127 times per minute, which is equal to 12.2 miles per hour. The first, or low gear is 27 to 1, or 5.8 miles per hour, while on the reverse, it is further decreased to 34.6 to 1, or 3.2 miles per hour. A substantial lock is provided to prevent attempting to engage two speeds, while a strong spring tends to throw the shifting lever into the neutral position whenever it passes that point. The complete gearset and its case weighs 600 pounds.

Frayer-Miller. The Frayer-Miller is a further type employing an air-cooled motor, and, in fact, was the first of its kind built in this country to incorporate a blower for cooling the engine. This blower, which is of the vane, or centrifugal type, takes the place of the fan ordinarily employed on water-cooled motors and is driven by gears from the crank shaft in much the same way, but, as its capacity has to be much greater, the construction throughout is very much more substantial. The blower delivers a large volume of air to a manifold which is led up and along the top of the cylinders, opening into the upper ends of light air-jackets which surround the heads and working length of the cylinders. The latter are fitted with radiating flanges past which the air is forced, issuing at the open ends of the bottom of the jackets. Contrary to the usual practice, the valves are placed in a vertical plane and face one another in a special valve chamber mounted on the cylinder head, thus getting the direct benefit of the cooling current of air. As motor trucks and delivery wagons are run at slow speeds and with frequent stops as compared with a pleasure car, the blower system, represented by the Frayer-Miller and the Franklin, is an advantage as it makes the cooling of the motor entirely independent of the speed of the car. In the truck types, the Frayer-Miller is listed in 1½- to 2-ton and 3-ton sizes. Except for slight differences of dimension, the specifications are practically identical in both cases. The motor has four 4¼-inch by 5⅛-inch cylinders and has a nominal rating of 28 to 30 horse-power. A selective sliding type of gearset, providing four forward speeds and one reverse and having its shafts mounted on annular ball-bearings, is employed. This is connected by a short propeller shaft having two universals to a countershaft, from which the final drive is taken to the rear wheels by side chains in the conventional manner. The axles are solid forgings of square section, 36-inch wood artillery wheels being used on both trucks, with 4-inch single, solid-rubber tires front and 3½-inch dual type on the rear of the larger machine, and 4-inch front and 5-inch single rear on the lighter type. The front springs are semi-elliptic, with a three-member semi-platform suspension at the rear. Both the foot brake and the emergency operate in drums on the driving wheels. The wheel base is 118 inches on the 2-ton and 128 inches on the 3-ton truck with a 66-inch tread, this permitting of a loading space measuring 12 feet long by 56 inches wide in the clear.

Rapid. By referring to "Gasoline Types of Delivery Wagons," Page 53, it will be noted that chassis of the smaller size just described are also listed as delivery wagons. This is the case with the Frayer-Miller, the makers of which list the smaller of the above chassis, with but slightly reduced dimensions, for delivery-wagon service. This is likewise the case with the Rapid, which, for delivery work, is of unusually substantial construction. In the case of the Rapid, the following differences in dimension suffice to sum up the points of variance between the one-ton delivery chassis, and the 1½-ton to 2-ton light truck. The two-cylinder, horizontal, opposed motor has a 5¼-inch bore by 5-inch stroke with an output of 30 horse-power, as compared with 24 horse-power for the smaller. 2-inch axles are employed with 32-inch wheels front and 34-inch wheels rear, the total weight of the chassis being 2,676 pounds, giving a comparatively high load efficiency, even on a 1½-ton basis.

But the difference between the requirements of heavy-duty trucks —in which class may be included those of 3-ton capacity and upward —and those of lighter weight is proportionately as great as the difference between the requirements of the pleasure car and the delivery wagon intended for constant service. The ratio of increase in the stresses imposed on the vehicle by an increase in the dead-load capacity was frequently not given sufficient consideration in the design of earlier trucks. It was often erroneously assumed that it was not even necessary to increase power and dimensions in quite the same proportion as the load increased. While this is true to a great extent, and particularly at the present time, it was not many years ago that neither materials nor design were up to the requirements. For this reason, some builders very prudently adhered to the manufacture of the lighter-capacity chassis for several years before attempting heavy-duty trucks, the experience gained in the former field being utilized to great advantage in the latter. The most common of early errors was naturally that of attempting to use practically the same chassis for commercial service as was used for the pleasure car. Under the greatly increased strain of commercial service, clutches, transmissions, and axles that did excellently on the pleasure car, here proved an unremitting source of trouble, which did much to discredit some of the first attempts.

A study of the conditions obtaining in the heavy-truck field, as compared with the requirements of lighter vehicles, is responsible for the striking difference shown in the design of the Rapid 3-ton and 5-ton trucks when placed beside those of the same cars for loads up to 2 tons. Instead of the two-cylinder, horizontal motor, a four-cylinder, vertical motor, Fig. 62, with cylinders of 4¾-inch bore by 5½-inch stroke, and giving 45 horse-power, is employed. By noting the different ratings and cylinder dimensions of the various truck motors described, it will be found that there is quite as much divergence in this respect in the commercial field, as in that of the pleasure car. Ample provision for lubrication—the prime necessity of the commercial car motor—is made on the Rapid by installing a gear-driven force-feed oiler with a capacity of 10 pints, a return pump taking care of the surplus oil in the crank case. As there are few things about the mechanism of a truck so essential to its operation as adequate provision for continuous lubrication, the equipment for this should be one of the first things looked to in examining a machine for its fitness for heavy duty. Next to this come the ignition and the cooling equipment, as upon these two depend in very large measure the reliability of the car. The Rapid trucks are fitted with a Bosch high-tension magneto—which constitutes an independent and self-contained system of great dependability—and a reserve system comprised of a four-unit vibrator coil and timer supplied by a set of storage cells. Two sets of spark plugs are employed, thus making each system entirely independent of the other. This is an excellent feature, as in the severe service which heavy trucks are called upon to perform, every precaution must be taken to insure absolute reliability, and while a high-tension magneto of standard make has proven to possess the highest measure of reliability, it is essential that the possibility of failure should be guarded against, as this might occur just at a time when a breakdown might mean the delay of a valuable load of merchandise in transit. The battery system is also a great aid in starting

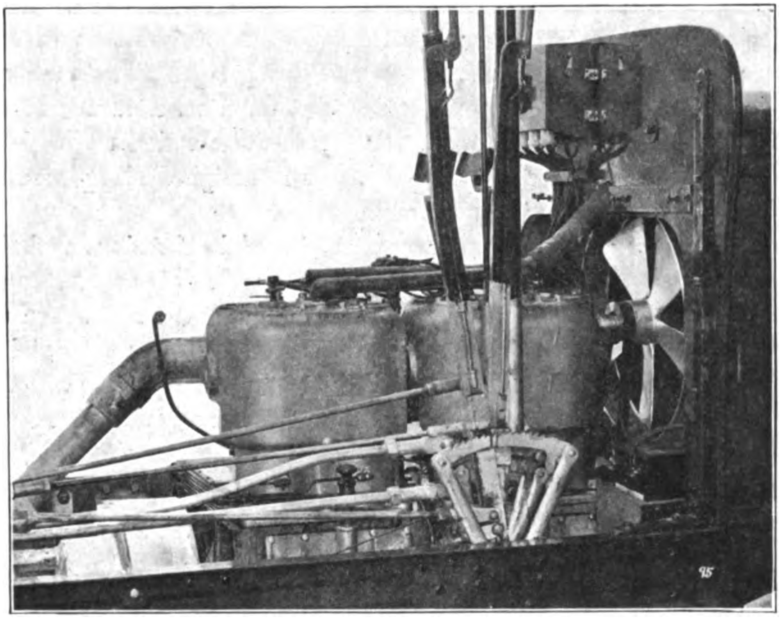


Fig. 62. Rapid 45-H. P., Four-Cylinder, Vertical Motor.

the heavy motors usually employed on trucks, as the motor will often take up its cycle simply by switching on the current, or with but little cranking, although the magneto has now been developed to a point which makes starting very easy, and thousands of cars carry no other ignition equipment.

The Rapid motor is cooled by means of a large radiator, mounted directly in front of the dash, the water being circulated by means of a gear-driven centrifugal pump. This type of pump has the advantage of permitting the water to circulate through it on the thermo-siphon principle in case it breaks down, which is not the case with the gear pump. The foregoing will make clear the reasons for the preference accorded the types of equipment in question on the best makes of trucks, the accessories in question now being regarded as standard, though in the case of the oiler and pump, there are naturally modifications of design to be found. So far as the remainder of its construction is concerned, the Rapid motor is designed along conventional and generally approved lines.

This likewise applies to the construction of the chassis as a whole, Fig. 63, every effort havihg been devoted to making it as substantial as possible. A heavy girder type of frame is employed with unusually large springs. The gearset is of the selective sliding type giving three forward speeds and is incorporated in the same housing with the differential on the countershaft. Heavy gears of wide face are used, the shafts being mounted on Timken roller bearings. The gear ratio is 7½ to 1 on the direct drive, giving a maximum speed of 10 miles an hour. The clutch is a multiple-disk type, running in a bath of oil, while the final drive is by means of heavy side chains, a feature of the drive being the use of a Hedgeland equalizing axle in place of the usual differential. This consists of a solid, one piece axle, with an ingenious screw clutch device for driving the wheels, which permits the outer one to run free when rounding corners. The front axle is of 2½-inch by 3¾-inch rectangular section, while the rear is a 3½-inch round steel section. Steering is accomplished by means of a differential-screw type of gear. The wheel base is 138 inches, giving a loading space of 12 feet in length. The weight of the complete chassis is 6,000 pounds.

The suspension of the Rapid trucks is of the conventional semi-elliptic front and half-platform rear springs, but is characterized by the use of an auxiliary spring over the rear axle, to supplement the regular springs when the truck is loaded beyond its normal rating. Trucks of this type are intended for the service of brewers, ice, coal, and lumber dealers, iron works, flour and sugar mills, and similar employment involving the transportation of heavy loads.

The vehicle just described is rated as having 3-ton to 5-ton load capacity, the same makers listing a heavier type designed to carry 5 tons to 7½ tons. Its specifications are the same with the exception of differences in dimension. A 60-horse-power motor is employed, the frame being of 6-inch rolled steel channels, with proportionally heavier axles and springs. The wheel base is 160 inches, giving a loading space of 14 feet, while the weight of the chassis is 7,500 pounds.

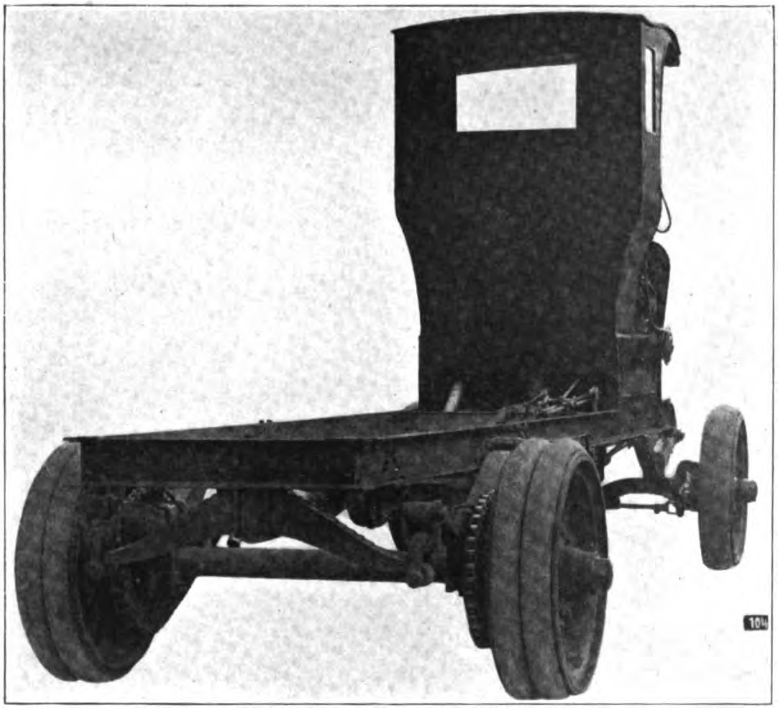


Fig. 63. Rapid 5-Ton Chassis.

American. The American trucks, which are listed in 1-, 1½- to 2-, 3-, and 5-ton sizes, are characterized by the use of a governed motor, a sliding gearset in the smaller sizes, a wood frame, and a special type of planetary, with disk clutches on the 3-ton and 5-ton types.

The governor employed on the motor is of the centrifugal type, acting directly on the throttle, and is a feature of considerable advantage in commercial work, as it not alone prevents racing of the motor between gear changes—which is detrimental—but may also be set so that the driver cannot exceed a certain speed. The 1½- to 2-ton size is fitted with a 35- to 40-horse-power motor, while a 55-horse-power motor is installed on the 3-ton size, and a 65-horse-power on the 5-ton size. Drive is by countershaft and double chain in the usual form, in every case, an I-beam axle being used forward and a solid square axle in the rear. The suspension is of the conventional, straight, semi-elliptic type forward and platform, three-point, spring member in the rear. A view of one of the American chassis is shown in Fig. 64.

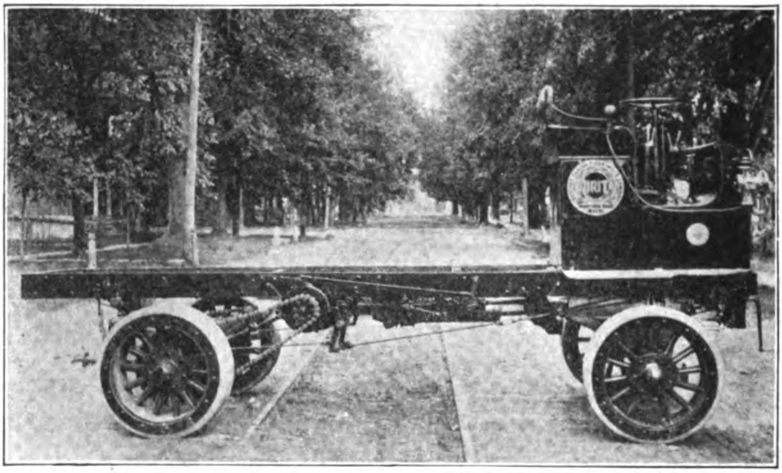


Fig. 64. American 5-Ton Truck with Wood Frame.

Manhattan. The Manhattan trucks are of considerable interest, as being among the first heavy types to be placed on the market in this country, their successful operation in sizes ranging from 2 tons to 5 tons, during the past six years, affording ample evidence of the benefits to be derived from a special study of the commercial problem, which led their makers to employ the most substantial type of construction right from the outset. The comparison of weights of chassis for a given load shows that they are considerably heavier than some of the others, so that their theoretical load efficiency would be correspondingly less, but the extra weight would appear to be justified by the record that these cars have made in service. The motor is a four-cylinder, vertical type, of 5½-inch bore by 6-inch stroke, but with characteristic conservatism, the makers refrain from giving it a power rating. Its output is probably 50 to 65 horse-power at a speed of 900 to 1,200 r. p. m.

The frame is of a heavy girder type and is carried slightly beyond the forward face of the radiator in bow form, providing a bumper which serves as protection for the radiator. This is a small detail but is of considerable value in commercial service as bumps are not infrequent and the radiator is the first thing to suffer. A leaky radiator is not alone a source of considerable annoyance, but also of danger to the motor, while a honeycomb type of radiator is difficult and expensive to repair. One of the features of the Manhattan trucks is the employment of an individual-clutch change-speed gear, Fig. 65. While this apparently does not differ from the ordinary sliding type, Fig. 61, it will be noted upon closer examination that the gears are not designed to slide, but remain constantly in mesh. When out of engagement, they are idle on the shaft, being locked by positive

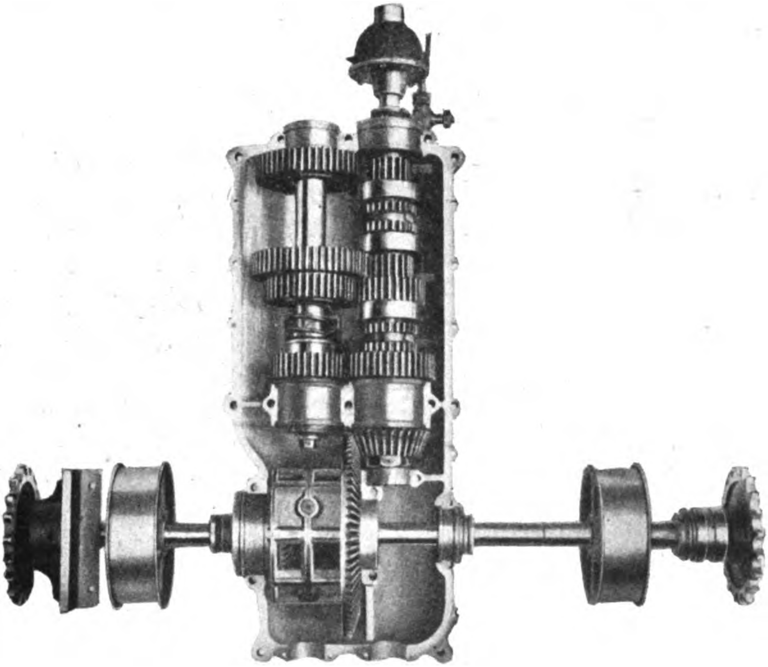


Fig. 65. Mack Transmission Used on Manhattan Trucks.

clutches controlled by the usual shifting lever operating in a standard form of H-gate.

The gears, of large diameter and wide face, are carried on substantial shafts supported on Hess-Bright ball bearings. The differential is of the bevel type and is enclosed in the same housing as the gearset, this housing being supported at its after end by the countershaft. From the latter, the drive is taken to the rear wheels by heavy side chains. The countershaft also carries two large drums of wide face, to which contracting bands are applied as brakes, the stresses of braking thus being balanced by the differential as well as by the usual equalizing gear. Internal-expanding emergency brakes are fitted on the driving wheels. The first service in which the Manhattan cars were generally employed was that of sight-seeing cars, station buses, and the like, having a capacity ranging from 12 to 22 passengers. A large number of these cars, fitted with various types of closed and open bodies are now in service. The construction throughout has been standardized by the makers, the same motor and gearset being used on all sizes from the 12-passenger, sight-seeing car up to the 5-ton truck, the difference naturally being in the manner of utilizing the power by varying the gear ratio between the motor and driving wheels. The small buses and sight-seeing wagons consequently are capable of speeds up to 25 miles an hour, while the heavy trucks run from 10 to 12 miles an hour loaded, and up to 15 or 16 miles empty. Owing to the gear ratios necessary to give these low speeds of travel, especially on the first and second gear changes, it would be necessary to race the motor unduly to exceed the speeds in question. For commercial service, the Manhattan chassis are built with capacities of 2, 3, 4, and 5 tons.

Packard. The Packard 3-ton truck, built by the manufacturers of the pleasure cars of the same name, affords an excellent example of the progress that has been made in the development of a truck designed to meet the most severe business requirements. It is the result of several years' study of the problem and was only placed on the market after a thorough trying out of the vehicle from every point of view. The motor is of the four-cylinder, vertical, water-cooled, four-cycle type and is characterized by the same features of design which distinguish the motor employed on the pleasure car. As is the case on the latter, the motor is carried on the forward end of the chassis

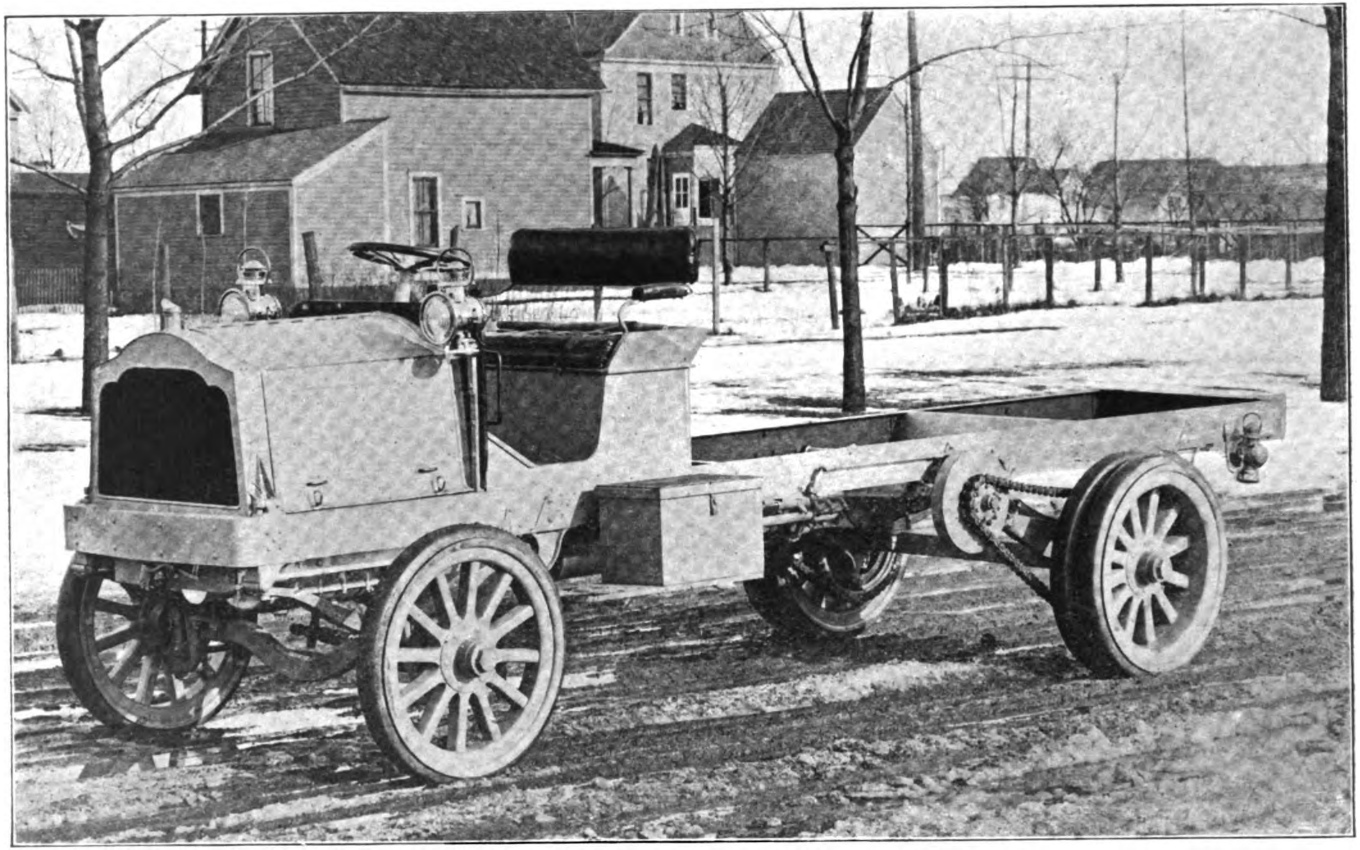


Fig. 66. Packard 3-Ton Truck, Standard Chassis.

under the same type of bonnet, Fig. 66. The cylinders have a 4½-inch bore and a 5½-inch stroke, the motor being designed to develop 24 horse-power at an unusually moderate speed. This makes it capable of giving an output largely in excess of this by simply increasing the speed of the motor, which, due to its low normal r. p. m. rate has a wider range of acceleration without racing than is possible with a higher initial rate. An unusually flexible motor thus results, and the importance of this feature may be appreciated when the low speeds of travel to which the commercial vehicle is necessarily restricted are borne in mind. In other words, the discrepancy between the motor speed and that of the car is greatly reduced, and the necessity for employing a high gear ratio correspondingly lessened.

Cooling is accomplished by means of a cellular radiator, the water being circulated by a centrifugal pump of large capacity. The radiator itself is carried on a trunnion type of mounting which prevents it being affected by any torsional stresses set up by the twisting of the frame. An Eisemann high-tension magneto is employed for the ignition, with a set of storage cells for reserve current. The clutch is what is known as a *dry-plate* type, in which a floating disk having both of its surfaces covered to a large extent with cork inserts, is clamped between plain metal disks secured to the flywheel and the transmission shaft respectively. Changes of speed are effected by means of a sliding gear of the same type as is employed on the Packard pleasure cars, final drive taking the form that has become standard practice in American heavy-truck design, viz, double side chains. To overcome the whipping and jerking effect on the chains occasioned by frequent changes of speed, the countershaft carries two heavy disks, one at either end, just inside the sprocket. These act as balance wheels and keep the countershaft rotating at a practically uniform speed. Heavy stresses suddenly imposed on the chains, as in starting large loads, and in changing from one speed to another, tend to stretch the links and throw the chain out of pitch with the sprockets, thus bringing about rapid wear and making the chains very noisy, while there is also danger of breaking a chain when the stress is more than ordinarily severe. This simple expedient is accordingly becoming generally adopted in truck work.

American Locomotive. An excellent illustration of the adaptability of the internal combustion motor for commercial service is afforded by the American Locomotive 3-ton truck, Fig. 67, in which the same motor is employed as on the taxicab made by the same manufacturers. This motor is of the standard four-cylinder, four-cycle, vertical type and is equipped with a governor. When adapted to cab use, the governor is set so that the motor cannot exceed the very moderate speed of 850 r. p. m. At this rate, it develops 16 horsepower and limits the speed of the vehicle to 20 miles an hour. On the truck, it is set for 1,000 r. p. m., giving an output of 24 horsepower and a speed of approximately 12 to 14 miles an hour. The motor is mounted directly under the footboards, and as the height of the frame when the car is loaded is 36 inches above the ground, this makes every part of the mechanism of the power-plant directly accessible. As shown in Fig. 68, the radiator is spring supported, the helical springs on the upper and lower ends of the rods counteracting

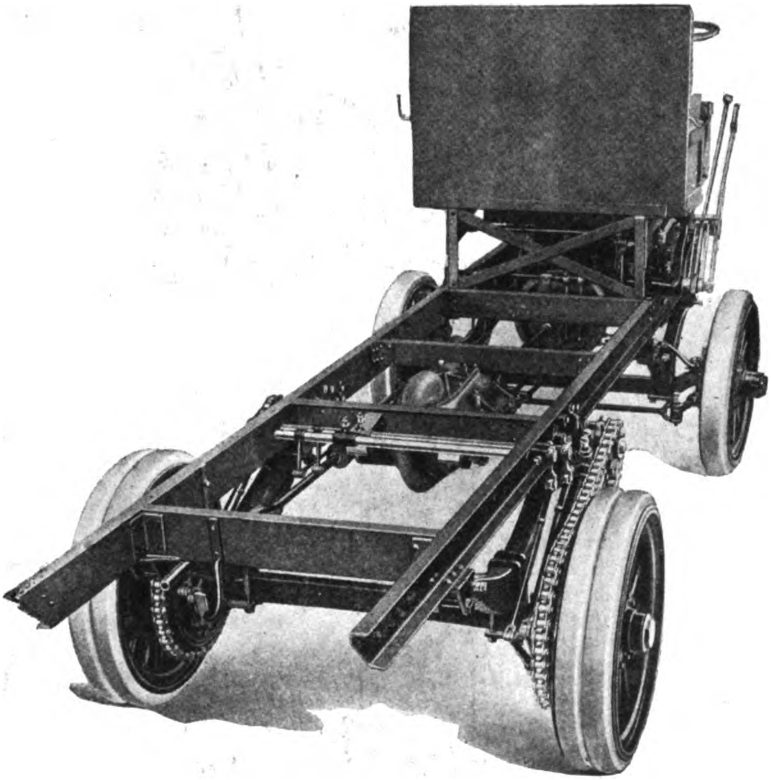


Fig. 67. Chassis of Alco 3-Ton Truck.

one another and entirely relieving it of the jolting and vibration which is unavoidable in a heavily loaded vehicle running on solid tires. The usual sliding type of change-speed gear, providing three forward

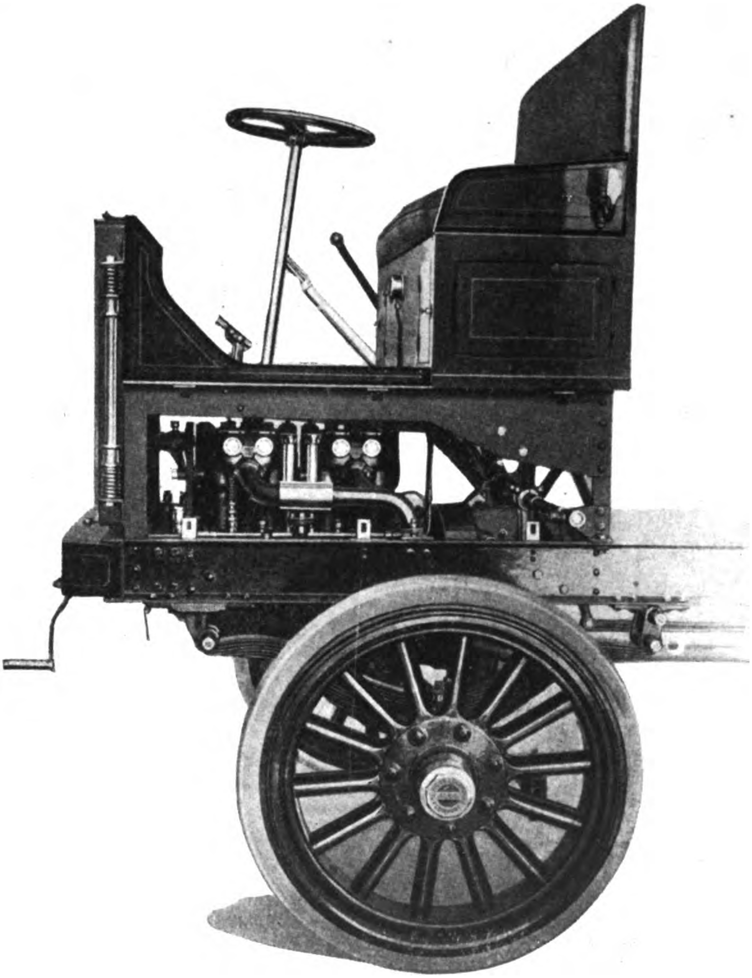


Fig. 68. Alco Truck, Showing Spring-Supported Radiator.

speeds and reverse, is encased in the same housing with the differential on a heavy countershaft, from which the drive is by side chains to the rear wheels. Solid one-piece axles of rectangular section are employed, the wheels running on Timken roller bearings. Straight semi-elliptic springs are used for the suspension at all four points. The length of the loading space is 12 feet with the standard body, the width being optional. Though of the most substantial construction throughout, the American Locomotive truck has an unusually high-load efficiency percentage, as the chassis weighs but 4,850 pounds, the weight of the 3-ton truck complete with the usual standard express body having a light frame and canvas top, being 5,260 pounds. It will be noted that while the loading space is as great as that provided in many of the 3-ton to 5-ton trucks already described, the wheel base is very short—but 110 inches, owing to the placing of the motor under the footboards, which eliminates the necessity for any overhang forward. The maximum width is approximately 78 inches over the rear hubs, this corresponding to a gauge of 66 inches, which is about the standard in trucks of this size and ranging down to 56 inches in delivery wagons.

If a resumé of the features of the various types of trucks already described were made, it would be found that, while all vary to a greater or less extent, the designer has, in every case, attempted to incorporate certain well-defined standards. These are summarized by the manufacturers of the Sampson trucks as follows:

I. Accessibility and interchangeability of all parts.
II. Engine and change-gear units must be unaffected by any distortion of the main frame.
III. Units should be so connected that any possible movement relative to each other is provided for.
IV. All bearing and working parts should be extra large, and thoroughly protected from dirt and moisture.
V. Brakes should be large and powerful, with provision for quick and easy adjustment.
VI. Lubrication should be most thorough and entirely automatic.
VII. All parts should be easily accessible for inspection and adjustment.
VIII. The greatest strength must be given every part, consistent with the avoidance of unnecessary weight.

Sampson. The engine of the Sampson truck, Fig. 69, is of the standard four-cylinder, vertical, four-cycle type, and is designed to give its rated output of 40 horse-power at a normal speed of 925 r. p. m., or a piston speed of 850 feet per minute, which the builders consider to be the limit for good practice in commercial work. Oil is delivered under pressure by a gear-driven pump to the main bearings, from which it is distributed by centrifugal force to the

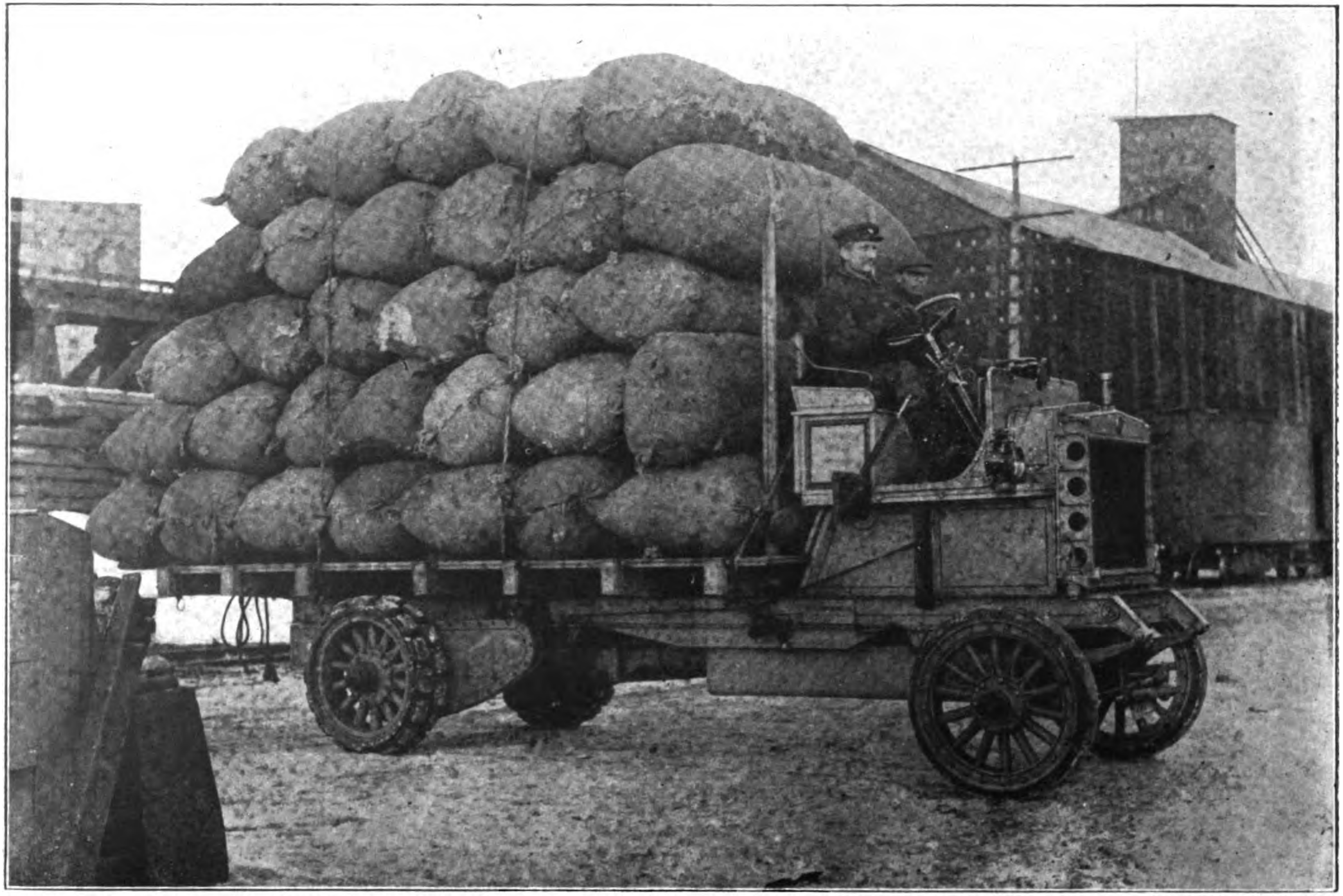


Fig. 69. Sampson 40-H. P. Truck.

crank pins; the pistons, wrist pins, and cam-shaft bearings being lubricated by splash. The valves and all bearings are of unusually ample proportions. The motor is located under the footboards and is mounted on a subframe, suspended at the rear from the main frame by flexible plates, and at the front by compensating springs of proper tension, thus relieving it of all strains caused by the twisting of the main frame when the vehicle is traveling over rough surfaces, and at the same time effectively cushioning it against the heavy shocks transmitted to the main frame by the stiff springs necessary to carry large loads. The gear-box unit, including the differential and service brake, is hung from the main frame by three spherically seated bearings, a single one forward being universally swung from a cross channel member, while the other two are riveted to the main-frame side members at the driving-sprocket pinions, thus, giving a flexible three-point support.

The radiator—of the vertical, gilled-tube type—is of very large capacity, the circulation being effected on the thermo-siphon principle, thus dispensing with a pump. It is designed especially for commercial service, being composed of a center containing the tubes and tube sheets, and with cast aluminum headers and sides. A spring mounting is employed in connection with spherical joints at the top, thus preventing any strain from being transmitted to it by the frame. In case of accidental damage, its mounting is so simple that it may be removed and a new radiator substituted in a few minutes.

The clutch is of the conical type using large cork inserts and having a balanced thrust. It is connected with the gear box by means of a shaft equipped with universals of the box type, and normally transmits the power of the engine in a direct line. The gear-set is of the sliding type with selective operation, giving four forward speeds and one reverse, and at the normal motor speed stated, is designed to give the vehicle speeds of 2½, 5, 7½, and 11 miles an hour for the 4-ton and 5-ton trucks, and speeds of 4, 8¼, 12, and 18 miles an hour, when fitted as buses.

Final drive is by heavy roller chains from the side shafts of the balance gear to sprockets bolted to and centered by the rear wheel hubs. A feature of the Samspon trucks is the use of a dust- and oil-tight housing, Fig. 70, which also acts as a distance member for the

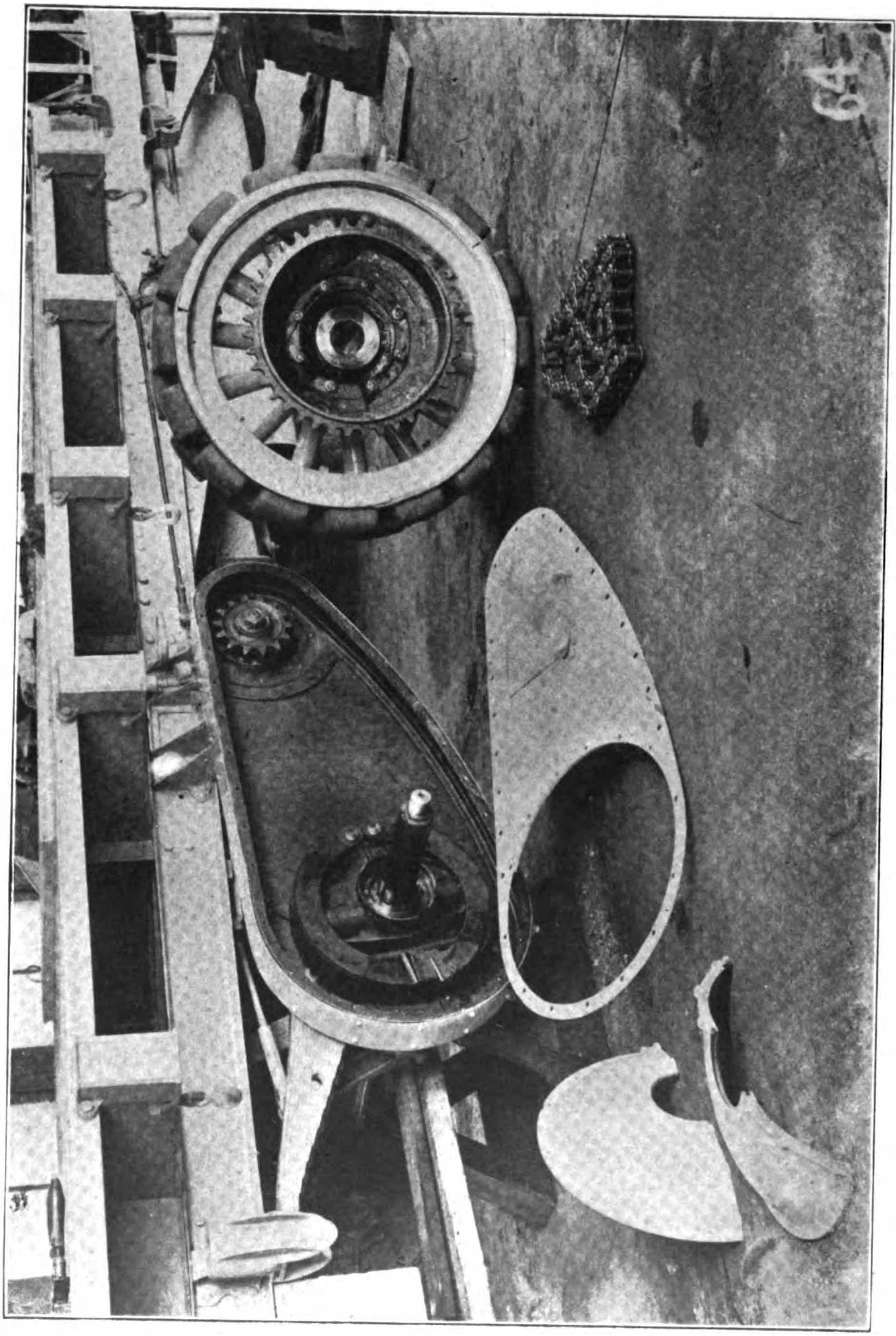


Fig. 70. Chain Housing on Sampson Truck.

rear axle, besides taking up the torque of the hub brakes on the driving wheels. The frame of the case consists of a substantial steel member of elliptical form, the sides being composed of light sheet steel. The entire case is hung on a spherical joint at the forward end and is hinged at the rear, thus relieving it of all strains. A simple and very accessible eccentric chain adjustment is provided to take up wear, the cases being provided with instantly removable covers which expose the entire chain and its adjustment. What this provision means in the added life and efficiency of the driving chains can only be appreciated by the condition of the outside of the chain cases, Fig. 71, after the vehicle has done a few hours' work on a muddy road. The life of an enclosed chain is several times that of one exposed to the mud and water, while the uniform and ample lubricant provided assures a high percentage of efficiency.

Hewitt. The Hewitt trucks are excellent examples of the result of long study devoted to the design of commercial vehicles of the heaviest types, as they are built in 5-ton and 10-ton sizes, and were probably the first of the latter capacity to achieve a commercial success in this country. The manner in which automobile practice has been modified throughout their design to meet the requirements of the transportation of heavy loads on a very economical basis, will be apparent from the following description: Ability to perform constant service of the most severe nature was adopted as the basis of the motor design, and it was constructed throughout with a view to standing up for long periods under the hardest kind of work. The bearings—which have always proved a source of weakness in commercial motors—designed after pleasure-car specifications, were increased in size considerably beyond any standard previously adopted for this essential. In fact, while the motor, Fig. 72, follows the usual automobile lines where compactness is concerned, it is really based upon stationary engine standards except where speed is concerned. The cylinder dimensions are 4½-inch bore by 5½-inch stroke, while the motor shows 36 horse-power at 1,000 r. p. m. Pistons and connecting rods are made of unusual length, in order to reduce the side thrust on the cylinder walls, a striking feature of the accessibility of the design being found in the fact that the pistons are readily removable through the side plates of the crank case by merely disconnecting. This permits of inspection and repair to any one of

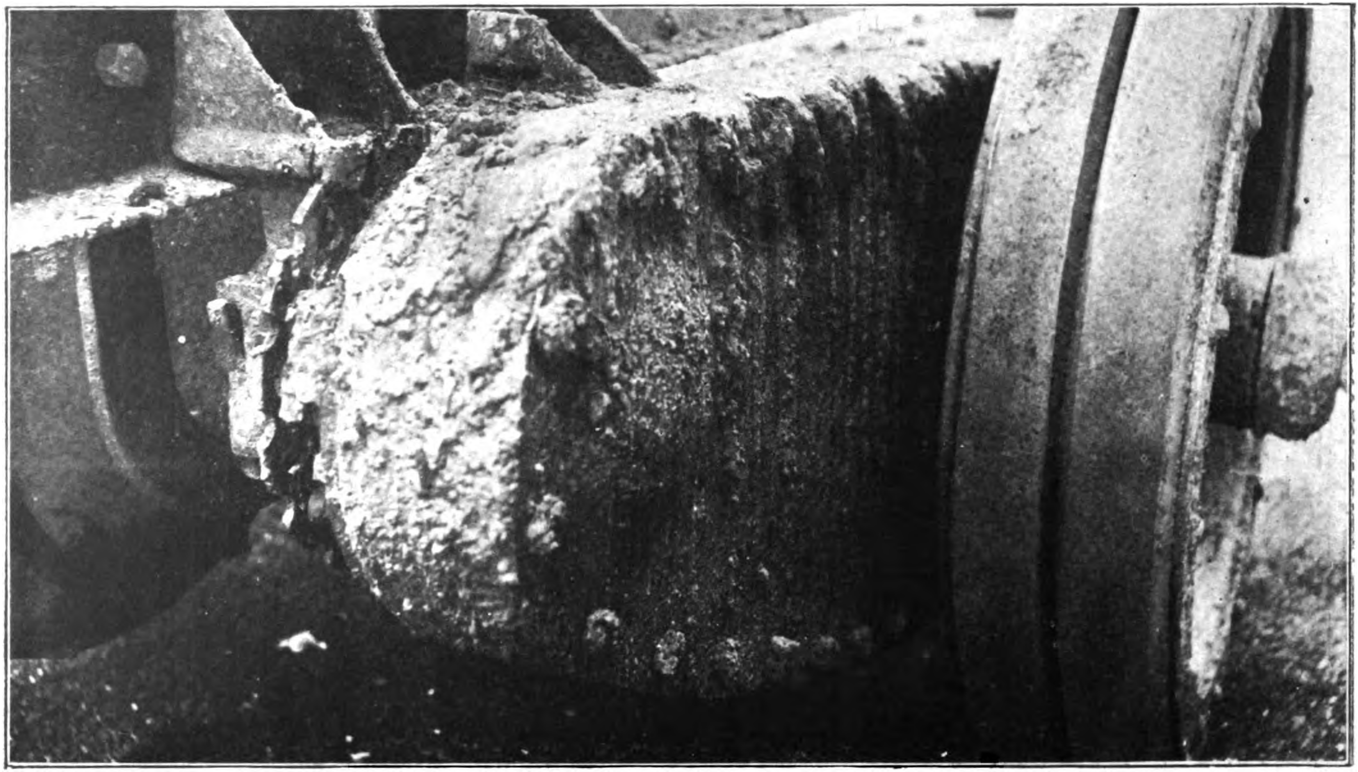


Fig. 71. Sampson Chain Case, Showing Its Value on a Muddy Road.

the pistons, without the necessity of dismantling the motor altogether, Fig. 73. Such a repair would ordinarily involve placing the truck out of commission for two or three days—an expensive item of maintenance with such a heavy vehicle.

Extra large, flat-seated valves are employed and an unusual volume of water is provided for in the jackets. The crank shaft is cut from a solid slab of steel and the cam shaft is a one-piece drop-forging. Oiling is entirely automatic, by means of a force-feed oil pump driven through gears from the cam shaft, while ignition is provided for by Bosch high-tension magneto running with a fixed spark. As already mentioned, the magneto itself is an independent, self-contained system, and, on the Hewitt truck, it is mounted so as to be removable in a few minutes, the designer being of the opinion that a second magneto carried in the tool box provides the best form of emergency equipment.

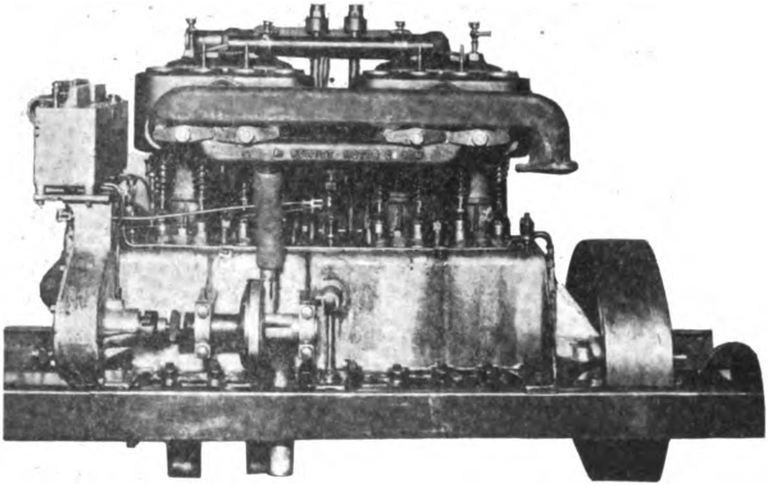


Fig. 72. Valve Side, Hewitt 5- and 10-Ton Truck Motor.

The same feature of interchangeability is carried out in the case of the radiator. This is of the Livingston cellular type and provides an unusually large cooling surface. As heavy trucks are subject to extremely severe vibration and jolting when running light, a special form of mounting has been adopted. The entire radiator is set in a steel case, surrounded by felt, and the case itself is suspended on compensating springs so as to relieve it of all jar. In case of accident, the entire radiator may be removed from the car and another substituted in a few minutes. A planetary type of change-speed gear of special form is employed, the method of control being one of the features of the Hewitt trucks. This control takes the form of three pedals, so that the driver is never called upon to remove his hands from the steering wheel. These pedals give the first, second, and reverse speeds respectively, and are so arranged that when one is pushed into engagement it locks there. By a special system of interlocking, pushing a second pedal automatically releases the first before the speed controlled by the second can be engaged, which makes the handling of a heavy truck extremely simple and easy. The truck is geared to make a speed of 8.6 miles an hour with the motor running at 1,000 r. p. m. 7 miles to 9 miles per hour is the most economic speed of operation loaded, while 10 miles an hour is a possible speed with an empty truck. Carrying a 5-ton load, the car is capable of running 4 to 6 miles on a gallon of gasoline and is capable of mounting grades up to 10 per cent with full load, Fig. 74

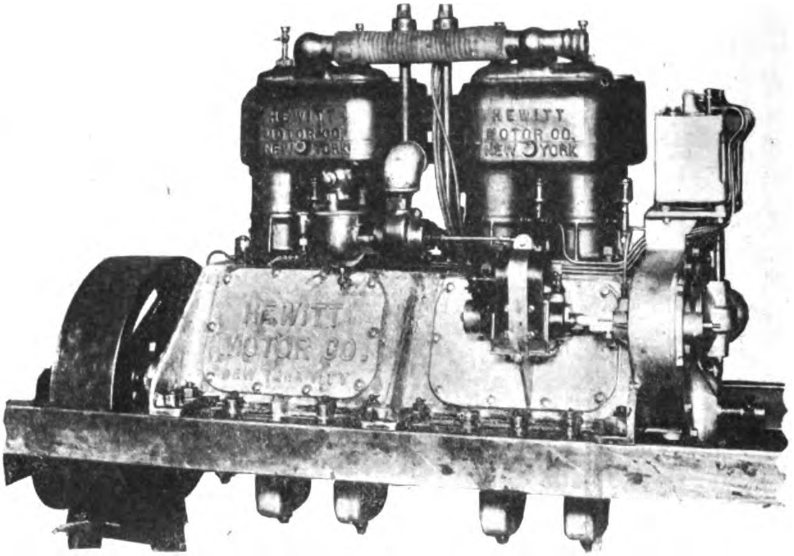


Fig. 73. Magneto Side Hewitt Motor Showing High Crank Case.

Hewitt 10-Ton. Contrary to general opinion, the chief difficulty experienced in the design of a truck to carry a load of 10 tons was not encountered in the motor or other parts of the mechanism, but in the provision of a tire that would give satisfactory service under this very heavy load, as with the weight of the car added, the pressure on the ground reaches 700 pounds per square inch. A tire formed of heavy rubber blocks, the construction of which is gone into more in detail under the subject of tires, was found to solve the problem. The motor is the same as that used on the 5-ton truck, but the speed of the vehicle has been reduced to a maximum of 6 to 7 miles an hour as this is as fast as it has been found safe to travel with such a great weight. In a truck of this size, the parts are naturally of massive dimensions, Fig. 75. For instance, the frame is of pressed steel, having side members 9 inches deep, while the clear loading space back of the driver's seat is 14 feet. The heaviest chains of 2-inch pitch are employed for driving the rear wheels, while roller bearings of special design were found to be necessary to carry the load imposed on them. The driving sprockets on the rear wheels are 36 inches in diameter. As is the case on the 5-ton truck, the special, two-speed, planetary gear with pedal control is employed. This runs in oil, the low and reverse speeds being operated by asbestos faced bands, while the direct drive is obtained by engaging a conical clutch. This is held in position by a plate, acting on a set of springs which give just the necessary pressure to drive the car, so that the clutch cannot grip suddenly. The supply of oil in the gearset is maintained by the same oil pump which feeds the crank case of the motor. In this, as well as other features, the specifications of the 5-ton and 10-

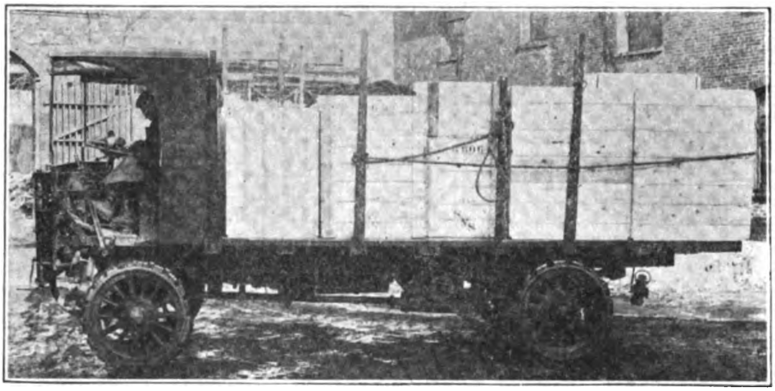


Fig. 74. Hewitt 5-Ton Truck.

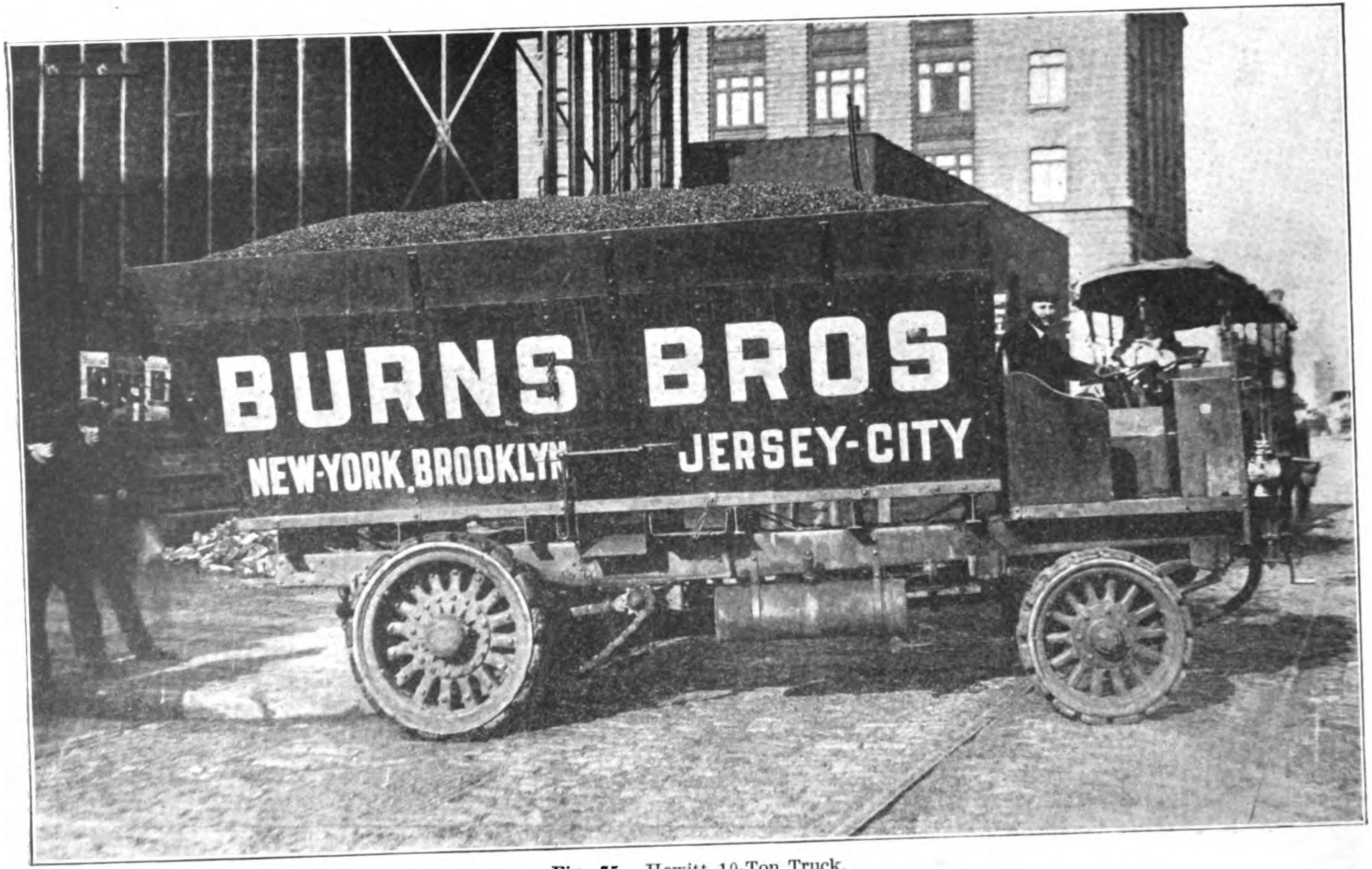


Fig. 75. Hewitt 10-Ton Truck.

ton trucks are the same. It is naturally out of the question to give trucks of this character a large overload capacity, as a number of the parts, such as the wheels, chains, tires, and the like must be worked up close to their safe limit in the original design, so that carrying a continuous overload would be apt to destroy their factor of safety in a comparatively short time. However, it has been found within the capacity of a 5-ton truck to haul a 5-ton trailer behind it, in addition to transporting its own full load, giving it a total capacity of 10 tons. Such trucks are specially designed for the carrying of coal, building materials, structural iron, and other heavy products which may be transported in bulk. This company also builds 2-ton and 3-ton trucks of the same general characteristics.

Two-Cycle Types of Trucks. *Reliance.* Mention has already been made of the fact that comparatively little attention has been devoted to the development of the two-cycle motor for commercial use, and this is particularly true where the heavier types of truck are concerned. So far as the writer knows, the only large truck of this type on the market at the present writing is the Reliance, which is listed by its makers up to 5-tons capacity. In this size, it is equipped with a four-cylinder, two-cycle motor of the valveless or three-port type, the dimensions of which are 5⅛-inch bore by 5-inch stroke, rated at 60 horse-power. This motor has been developed especially for commercial service and has numerous features of merit, one in particular being the possibility of adjusting the main crank-shaft bearings from the outside of the case, while the connecting-rod bearings may be reached simply by removing a plate from the bottom of the crank case. As the only moving part protruding from the crank case is the crank shaft itself, the motor accessories are driven directly from it at the forward end. The drive takes the form of a spiral gear meshing with a pinion on a vertical shaft which is directly attached to the gear pump below. This shaft also carries the timer at its upper end and drives the force-feed oiler by means of gear attached to it at a point where the shaft passes directly through the oiler, thus making this part of the motor quite as compact and self-contained as the remainder, Fig. 76.

The radiator is of the honeycomb type and is supported on rubber cushions in a steel channel case. The latter is held by means of ball and socket joints, so that no torsional strains can be transmitted to it, while no bolts or studs are attached directly to the radiator, which may be removed from the casing in a few minutes. Ignition is by means of a four-unit coil and timer, supplied with current by two sets of storage batteries. The carbureter is of the conventional float-feed type with automatic auxiliary air intake such as is commonly employed on four-cycle motors, and is attached to a manifold communicating with the third port of each cylinder. When the latter is uncovered by the piston on its upward stroke, a charge of gas exceeding in volume the capacity of the combustion chamber of the cylinder, is drawn into the crank case. On the following downward stroke of the piston, which, of course, is a power stroke, the fresh charge is compressed in the crank case, and when the piston reaches the lower limit of its stroke, it uncovers another port and the charge is quickly transferred to above the piston.

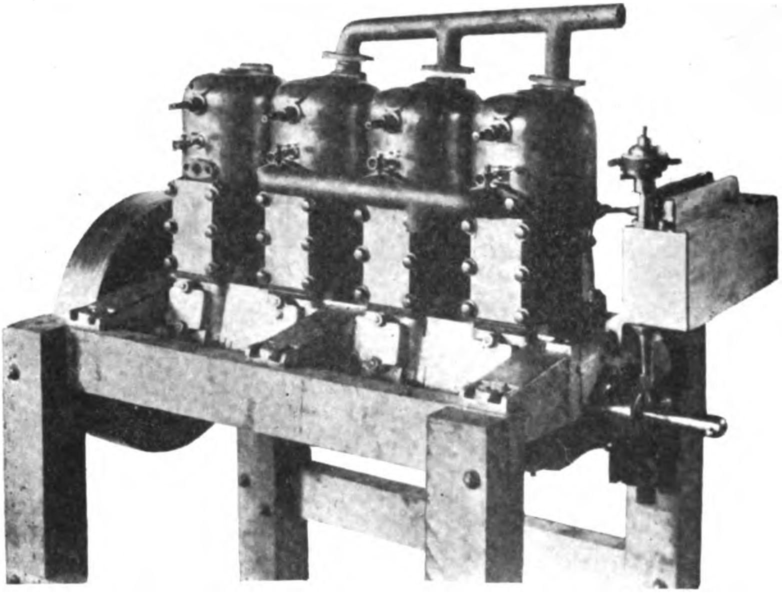


Fig. 76. Reliance Four-Cylinder, Two-Cycle, Truck Motor.

The clutch is of the standard conical, leather-faced type of the simplest form and it is disengaged automatically by the application of either brake. The gearset is carried in the same housing, but separated by a partition from the differential and bevel drive of the countershaft. It is connected with the clutch by means of a short shaft and universals. The gearset itself is of the progressive sliding type, providing three speeds forward and reverse. The shafts are carried on annular ball bearings; the differential is of a special type and has its shafts mounted on adjustable roller bearings. A three-point support is employed to carry the transmission case, which is of cast iron. In the design of the remainder of the Reliance truck, conventional lines have been closely followed. As is the case with any of the trucks employing a double, side-chain drive, the speed of the vehicle may be altered to suit the conditions simply by changing the size of the forward, or driving sprockets.

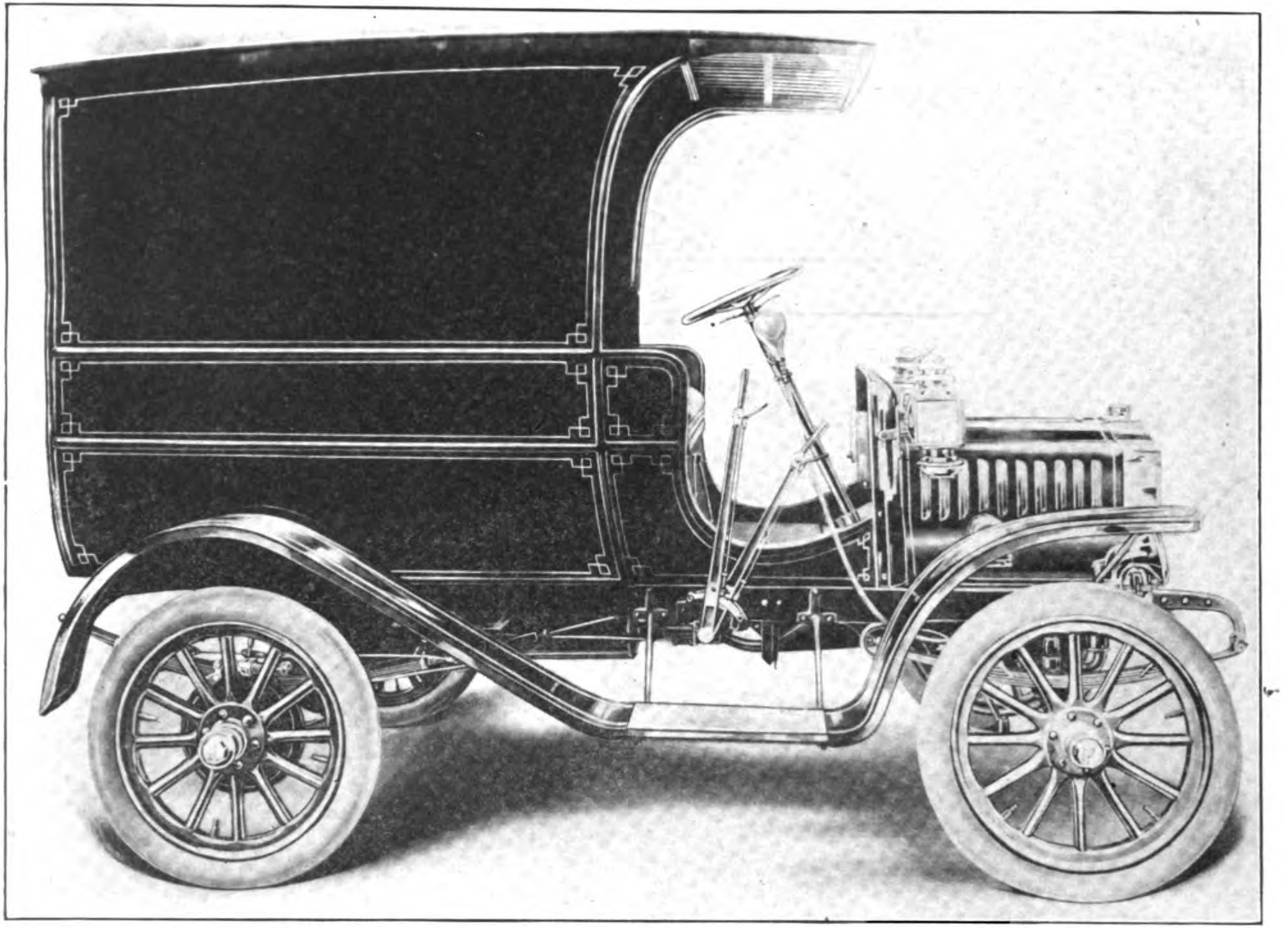
What Future Developments May Be. In the foregoing, no attempt has been made to cover the entire field of American commercial car design of the gasoline type, but merely to cite a number of representative examples to illustrate the present trend in practice in what is admittedly one of the most important branches of the automobile industry. But in a work of this nature, it is quite as important to attempt to look beyond the present as it is to portray what has been done and what is now considered to be the highest type of achievement in this field.

Electric Transmission. It will be generally conceded by engineers that while the sliding type of change-speed gear has been successfully developed to a high degree of efficiency and dependability in spite of great obstacles, it leaves much to be desired. With improvements in material and design, it has survived despite its shortcomings, simply because nothing better has come to light. That it will continue to hold its place is at least open to question, for the transmission is a feature of such vital importance in connection with the internal combustion type of motor that attempts are constantly being made to improve it. Many of these have taken the form of an electric transmission of the power, and the details of the systems of this nature that have come into actual use are dealt with at length under "Gas-Electric Vehicles."

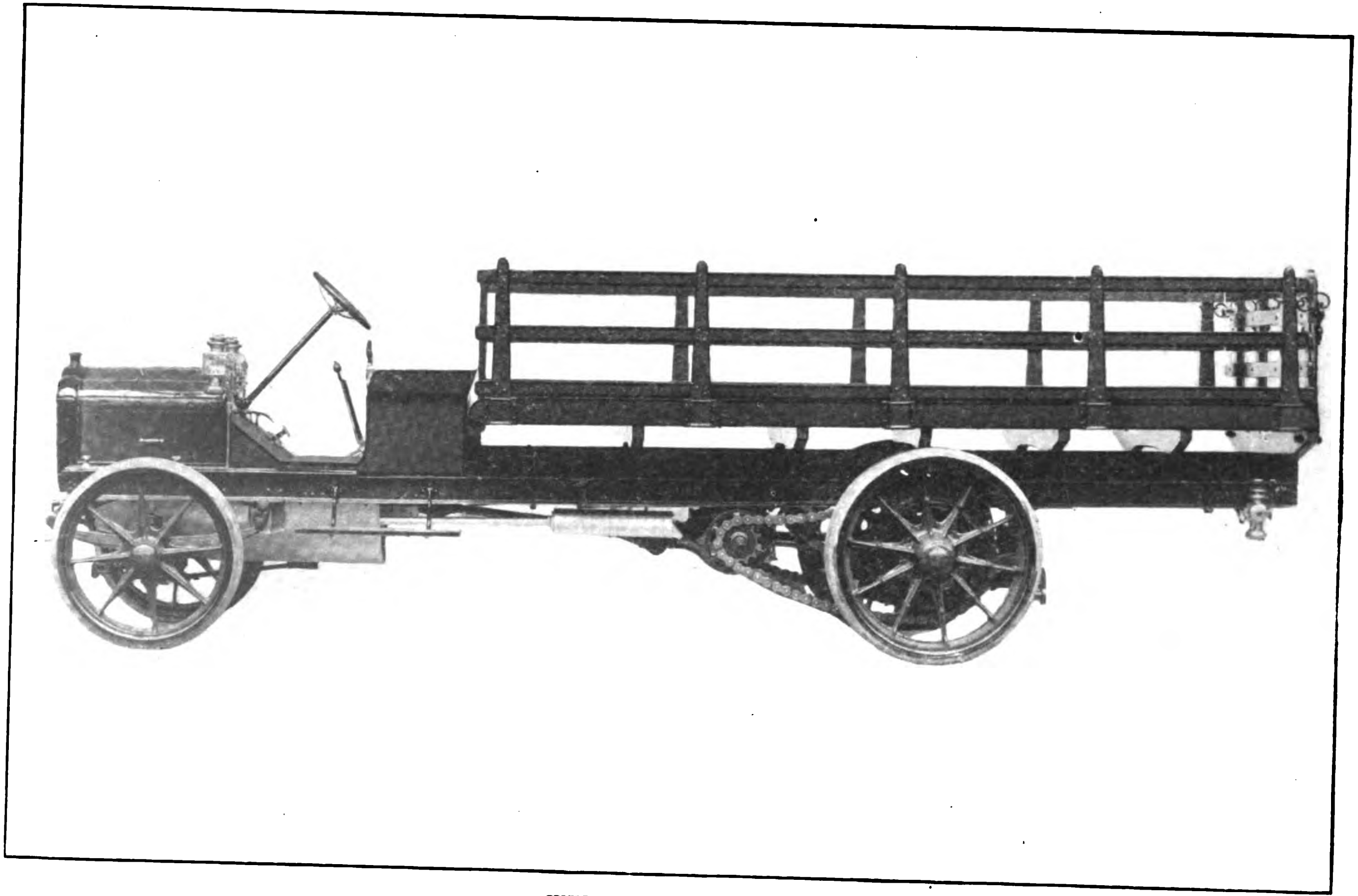
Manly Hydraulic Transmission. Another substitute for the gear drive is the Manly hydraulic, variable-speed transmission, in which a small hydraulic motor is directly connected to each driving wheel; thus all four wheels may be driven, instead of only two. The liquid—handled by a pressure pump which is run by the motor—is ordinary mineral oil of a low freezing point and low viscosity, in order to insure free flowing qualities in all weather conditions. As the motor may be run at a constant speed, entirely independent of the rate of travel of the vehicle, its duty simply consists in subjecting the supply of oil to pressure. The minimum is about 200 pounds to the square inch, and the maximum 2,400 pounds, and, as might be expected, the system of valves and motors to properly handle such pressures, must be well designed and better constructed. The oil under pressure is admitted by a single lever directly to the hydraulic motors, which are connected to the driving wheels. This lever operates a special valve system giving the entire range of speeds ahead, as well as reverse.

A truck fitted with a transmission of this character was in service for a year, mostly in New York City streets, and carried a maximum load of 8,500 pounds. During that time, the machine covered a total of 3,000 miles over poor pavements and an examination of its condition at the end of that time revealed a further and particularly important advantage, viz, its tire economy. The speeds vary from a mere crawl to the maximum, and as starting is very easy and gradual, the tires are never subjected to the harsh treatment that is more or less unavoidable with the sliding gear.

In view of the manner in which the sliding gear has persisted, despite its detractors and all prophecies to the contrary, it would be rash to attempt to predict what the next decade may bring forth in the shape of an improvement. Whether the electric transmission can be developed to a point where the additional weight and higher initial cost will permit it to compete on almost equal terms with the mechanical type on medium weight vehicles is a question that the next few years should solve. From the experience with the Manly truck as well as from experiments along the same line that have been carried out abroad, it is evident that the hydraulic type of transmission is a future possibility.



MAXWELL TWO-CYLINDER. TWENTY-HORSE-POWER DELIVERY WAGON
Maxwell-Brisco Motor Co., Tarrytown, N. Y.



WHITE GASOLINE TRUCK
Load Capacity, Three Tons.

COMMERCIAL VEHICLES

PART II

GASOLINE-DRIVEN TRACTION ENGINES

Under this head falls a type of machine that at first sight will doubtless strike the average reader as not coming within the category of the commercial vehicle at all. But it represents an extremely important branch that is just beginning to come into its own and which, in the course of the next ten years or so, is destined to prove a powerful factor in the elimination of the horse from many classes of work now entirely monopolized by animal traction. Haulage has formed but a comparatively small part of the work of the gasoline traction engine thus far, and doubtless represents a rôle in which it will not be generally used for some time to come; it is rather in the carrying out of purely agricultural operations on the large scale demanded by modern farming that it has shown itself to be of the greatest value.

Strange to relate, the idea of substituting the power of the internal combustion motor for that of the horse in farming operations was first advanced in countries where the need for it was least. On the extensive farms of the Western United States, horses are needed in such numbers to carry out the work that their value exceeds that of the machine which displaces them. The reverse of this, of course, is one of the greatest hindrances to "scrapping old equipment" and adopting a power vehicle of any kind. In France and England, however, where the gasoline-propelled tractor has been under development for several years, farms are small, though crops are larger in proportion. The United States has always led in the invention and manufacture of agricultural machinery, so that it was not long before attempts were made to apply the gasoline engine to this purpose. The value of machinery for such operations as plowing, harrowing, and seeding on a large scale, had long ago been recognized in

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the adoption, to a limited extent, of steam traction engines, many of which are in use today. The disadvantages, however, of this form of power for farm use, especially in the West, had prevented its widespread adoption. The chief of these disadvantages was the expense for fuel as well as the difficulty of obtaining it in many sections of the country, while the low efficiency of the machine as a whole made its use impractical even with comparatively cheap liquid fuels, such as gasoline and kerosene.

The interest taken in agricultural tractors abroad will be manifest when it is recalled that an International, Agricultural-Motor Exhibition was held at Bourges, France—one of the most highly-developed agricultural districts in the world—in the fall of 1908. The chief competitors in the trials held were tractors of American, British, and French make, the last-named being of the type designed to haul the plows or other tools across the field by means of a drum and winding cable. This system had also been tried out in California and was seen to possess obvious disadvantages. It failed to score on the occasion in question, while the American tractor, true to the standing it has achieved the world over, easily carried off the honors. The machine in question was a tractor built by the International Harvester Company.

Tractors Follow Stationary Engine Practice. Tractors generally show more strongly than any other type of power vehicle now in use the influence of stationary engine practice. Students of automobile engineering will recall that the first attempts at automobile design in this country consisted of nothing more than the adaptation of the ordinary stationary engine to a running gear, and further that it was the dogged adherence to this abortive combination that did so much to keep the American automobile so far behind its European competitors in the first years of the last decade.

As a matter of fact, the majority of present-day gasoline- or kerosene-driven agricultural tractors are little more than stationary engines of the horizontal type, mounted on a running gear suited to the needs of the machine. It does not follow from this that the design is a poor one for the purpose, as was the case with the automobile, as the conditions of service are totally different. Speeds are necessarily very low, as plows or other tools could not be handled properly at a rate of travel in excess of a few miles an hour, while weight is a desideratum, rather than otherwise, in order to obtain the tremendous tractive power needed to start and haul loads involving such a great drawbar pull as is required to break a number of furrows in hard soil. As the loads are heavy and operation is continuous, economy must be considered, and the slow-speed, long-stroke, one- and two-cylinder engines employed are best adapted for this purpose.

International. The International tractor mentioned is practically nothing more than one of the stationary engines of this make, mounted on the platform of a heavy, four-wheel truck, Fig. 77. It may appear superfluous to mention that the latter has four wheels, until it is added that several types of tractors employ but three, in which 80 to 90 per cent of the weight of the machine is centered over the driving wheels, the third wheel merely acting as a guide. The engine in question is of the long-stroke type with the valves in the head, the exhaust valve being mechanically operated, while the inlet valve is automatic; the governor, as is customary in stationary practice, is of the hit-and-miss type acting on the exhaust valve. In governors of this class, centrifugal force is taken advantage of to make the exhaust valve rod hit or miss the valve tappet, opening the latter or allowing it to remain open, according to the speed and the requirements of the load. As the automatic inlet valve depends upon atmospheric pressure for its operation, it cannot open unless the exhaust

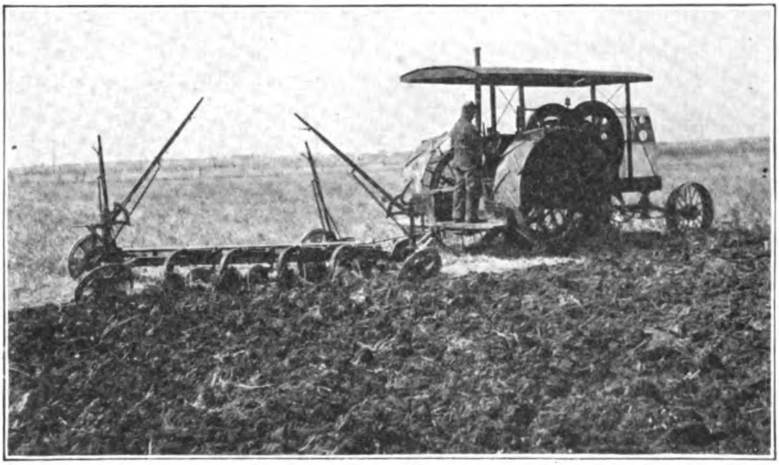


Fig. 77. Gang Plow with Gasoline Motor Tractor in Heavy Soil.

valve has closed on the stroke just preceding, so that no fuel enters the combustion chamber except when an explosion is necessary. As the governor is also usually designed to trip the igniter mechanism out of action at the same time, such engines are very economical of both fuel and electric current. The cylinder is of large bore and a low compression is employed as compared with automobile motor practice, two huge flywheels being utilized to give the engine a smooth running balance. It is cooled by means of a modified form of water tank, placed forward. This is provided with a large, wire gauze screen with sloping sides, over which the hot water is sprayed immediately on leaving the water jacket, then is collected in the tank below and circulated.

The engine is mounted on a heavy channel iron frame, to which is bolted the subframe carrying the stub axle brackets. The front axle is arched and well trussed, and is provided with a ball-and-socket connection. The stub axles at the rear fit into heavy axle brackets. The drive wheels are entirely of metal, having 56-inch diameter and an 18-inch face; they have heavy lugs bolted to the tires to provide ample traction, even on soft ground. Two friction clutches are employed, a large one for the forward speeds and a smaller one for the reverse. The drive is through two sets of pinions and large gears, a sliding pinion on the crank shaft of the engine driving a large differential gear on a countershaft carrying two pinions at its outer ends, which engage large gears on the road wheels. The forward clutch has three shoes, with large friction blocks which engage the surface of a drum or pulley. Reverse is obtained by shifting a lever, which throws the large clutch out of engagement, and engages the small one, which drives an intermediate gear. The same lever gives both the forward and reverse speeds, while a foot lever applies a band brake operating on the differential. Steering is accomplished by means of a hand wheel, worm gear, and chains attached at two points to the forward axle.

The foregoing serves to describe the small-size International tractor, which is fitted with a 15-horse-power, single-cylinder engine, though it also generally covers the construction of the larger sizes, which have a 20-horse-power engine of the same type, with driving wheels of 64 and 70 inches in diameter, the gear drive also being somewhat modified to meet the requirements of the heavier machines.

The largest size is equipped with a friction reverse which may be engaged while the machine is moving forward without danger of stripping gears.

Abenaque. Tractors such as those described are designed principally for use on level land, or where gradients are very easy, such as are found on the large farms of the Middle and West. The Abenaque is a machine that has been developed for the hilly regions of New England. The engine is of the horizontal type usually employed for stationary and portable service, but is equipped with a special cooling device, consisting of two narrow steel tanks, mounted directly on it.

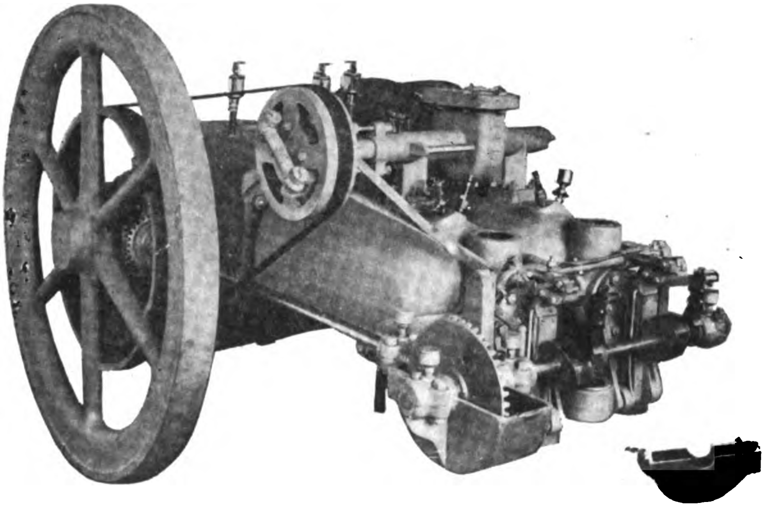


Fig. 78. Motor of Hart-Parr Traction Engine.

This makes possible the use of a greatly reduced quantity of water, while the head thus available assures a good circulation on the thermosiphon principle. As they have been designed for hill and bad road work, these traction engines are equipped with three gear changes, giving forward speeds of one, two, and three miles per hour, and a reverse, all controlled by a single lever, the arrangement of gear changes being on the selective principle now almost universal on the automobile. The clutch is operated by a pedal, or long foot lever, and is of the type recognized as standard on hoisting engines. In appearance, the Abenaque tractor does not differ materially from the usual portable gasoline engine mounted on a wheeled platform.

Hart-Parr. The Hart-Parr tractor which has achieved considerable success, was one of the first to depart from the practice of employing the ordinary stationary engine as its motive power. As will be seen from the illustration, Fig. 78, the engine is of the two-cylinder horizontal type, the cylinders being placed alongside of one another, and having all the valve mechanism in the head, thereby making it very accessible. The crank shaft has the two throws placed 180 degrees apart, so that the heavy pistons are always moving in opposite directions. This gives an excellent mechanical balance and accounts for the single flywheel of greatly reduced size. The entire engine is enclosed, as in automobile practice, thus excluding dust and grit which is frequently present in large quantities in the service for which these machines are employed. It is lubricated by splash in the crank case, fed by two force-feed oilers. The use of an auxiliary exhaust valve, or port, uncovered by the piston just before the end of its outward travel on the power stroke, is also a feature of this engine that insures cool running under the heaviest loads.

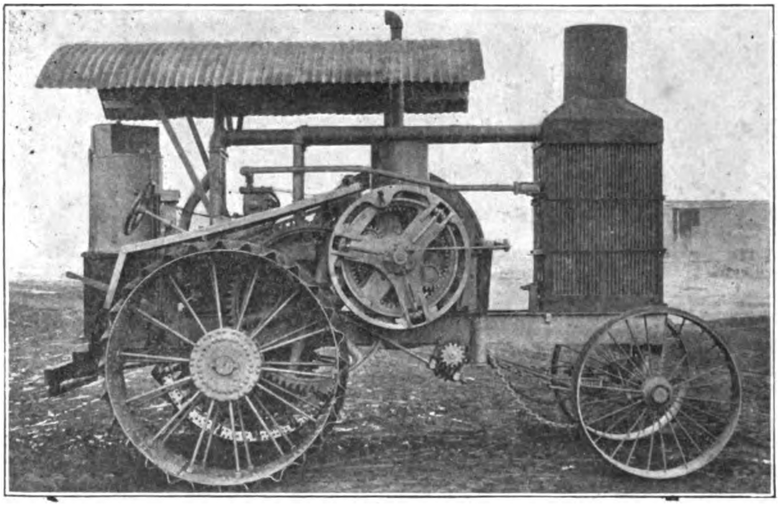
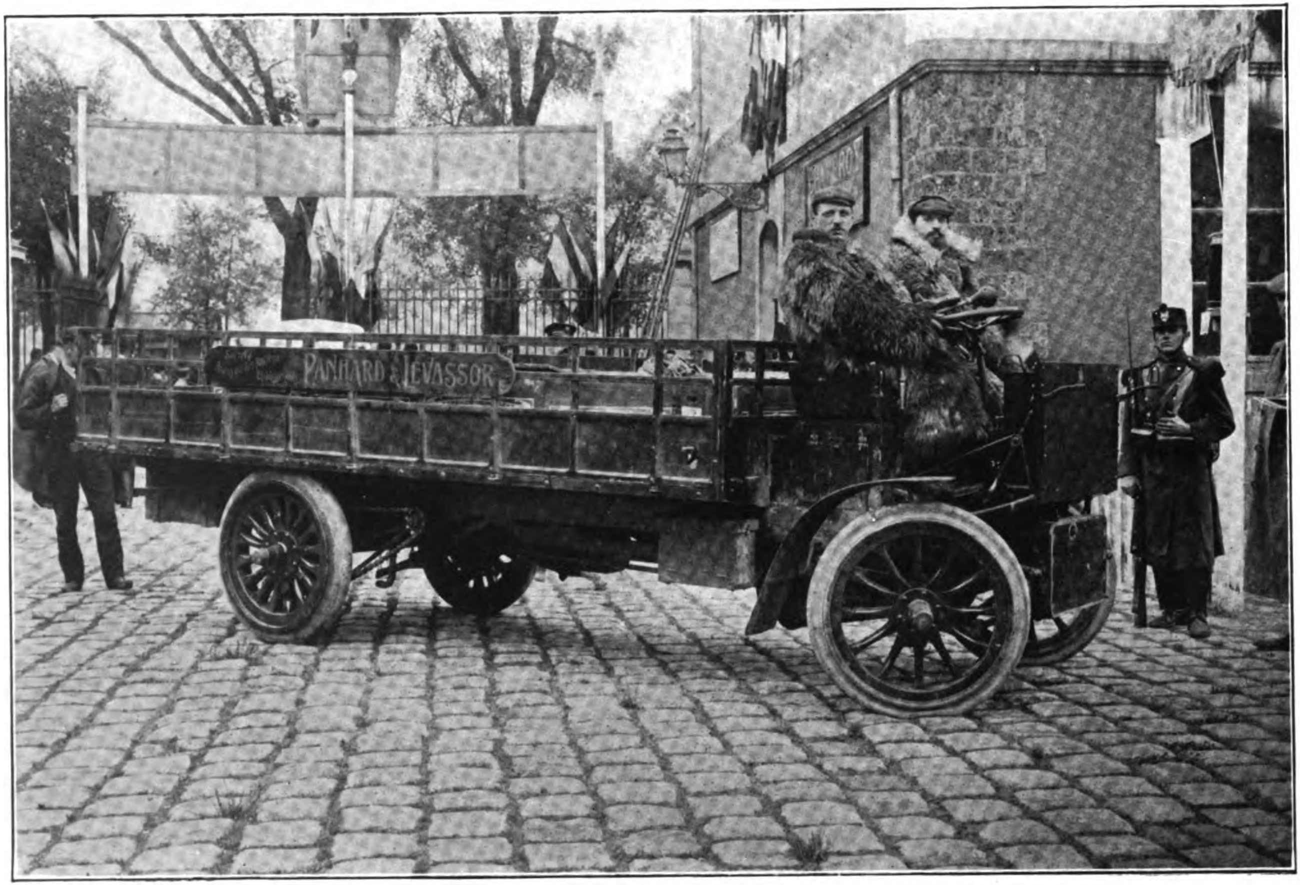


Fig. 79. Hart-Parr Traction Engine.

An original and ingenious system of oil-cooling is employed, making it unnecessary to take any precautions to prevent freezing in cold weather. As will be seen from the illustration of the complete Hart-Parr machine, Fig. 79, this consists of a special type of radiator



FRENCH AUTOMOBILE TRUCK
Built by Panhard & Levassor.

mounted on the forward end of the platform. This radiator is formed of a number of thin corrugated sections, covered by a conical hood and a short stack. The supply of oil is circulated through these sections of the radiator and through the jackets of the cylinders by means of a centrifugal pump mounted directly on one of the cylinders. The exhaust from the engine is led into the hood over the radiator, and in the upper faces of the exhaust pipes under the hood are drilled a large number of small holes, causing the exhaust gases to be discharged upward in numerous fine jets, which not only act as a muffler, but also set up a strong draft of air through the radiator. As the oil never reaches a temperature sufficiently high to boil it, and there is no waste, the original supply should last as long as the engine, barring accidents. The engine is capable of delivering 45 horsepower, according to the usual rating, but as the machine is intended to displace 22 draft horses, the tractor is given a nominal rating of the latter figure.

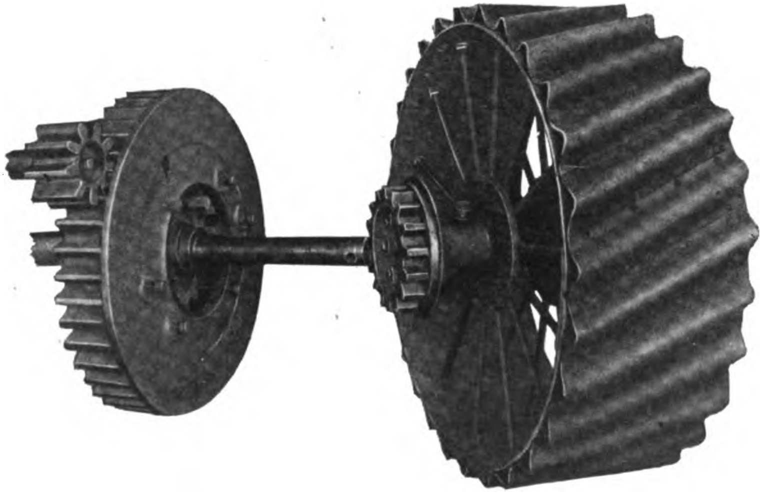


Fig. 80. Differential and Drive of Hart-Parr Tractor.

The driving wheels measure 66 inches in diameter and are driven through a train of gearing. Between the latter and the engine are interposed friction clutches of approved design, one being employed for the forward speeds and one for the reverse, both operating through a single lever; the traction gearing may also be independently disengaged from the engine, the clutch operating lever then giving a forward or reverse motion to the power pulley for driving machinery. The reversing clutch is also utilized as a brake. For ordinary traction service, the Hart-Parr engines are geared for a speed of three miles an hour and are fitted with the usual bevel gear differential. The drawbar pull required for plowing is so heavy, however, that for this latter service, they are equipped with the substantial spur gear differential, shown in Fig. 80, and are geared for a speed of 2½ miles an hour.

To meet the demand for an engine capable of employing the lowest grades of fuel, the Hart-Parr tractors are also fitted to burn either kerosene or crude petroleum, this being a decided advantage in remote districts in the United States, and particularly in foreign countries, where gasoline is either prohibitive in price or not obtainable at all. These tractors can likewise burn alcohol by making a slight modification, and it is anticipated that this fuel will be largely used in farm work in the future, owing to the constant upward trend of the cost of all petroleum products and particularly gasoline, as influenced by the automobile demand. When using kerosene or crude oil, the engine is started with gasoline from cold, the tank being specially designed to carry in addition to the regular fuel supply, a small quantity of this fuel for starting. Two sizes of the Hart-Parr tractors are listed, the 22-horse-power size just described, and a smaller machine having a nominal rating of 17 horse-power. The latter weighs 7½ tons, while the former is one ton heavier, and the plowing engine of the higher power weighs 9½ tons. The bore and stroke are 9-inch by 13-inch in the 17-horse-power engine, and 10-inch by 15-inch in the larger size, the engines running at 280 and 300 r. p. m., respectively, and making 17.3 turns of the crank shaft to one revolution of the driving wheels. The experience of several years in the handling of a large number of engines employed in various capacities, shows that they will operate 10 hours per day doing the heaviest class of work on a fuel consumption of 25 to 40 gallons of kerosene or gasoline, according to size.

Avery. As will be noted by its general outline, the Avery tractor, Fig. 81, represents a close approach to automobile practice and is a total departure from the types previously described. It is, in fact, a type of commercial vehicle designed for farm use, and it will be apparent from the following description of its construction that it is intended for a wide range of utility. The power plant consists of a four-cylinder, high-speed gasoline motor placed forward on the frame and under a bonnet, or hood, as is the case in the usual gasoline driven truck or pleasure car. Cylinder dimensions are 4¾-inch bore by 5-inch stroke, the motor itself being of the standard four-cylinder, vertical type. It is nominally rated at 12 horse-power, but shows a brake output of 36 horse-power. The engine auxiliaries are the same as employed in automobile usage, such as a float feed carbureter, high tension ignition by means of a magneto with storage battery in reserve, and cooling by pump circulation through honeycomb radiator, mounted as usual except that the frame forward has been narrowed to the width of the radiator itself.

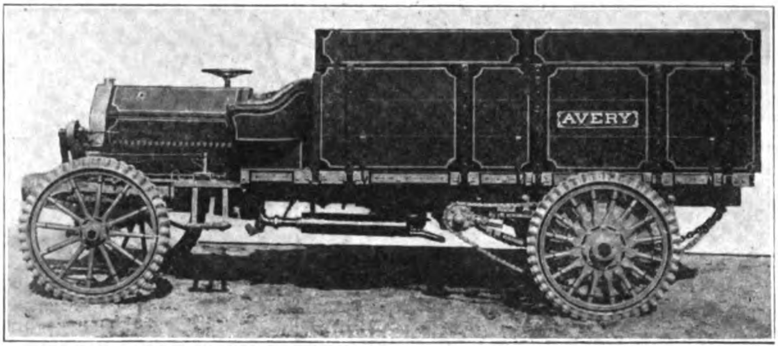


Fig. 81. Avery Tractor.

The power is transmitted through a standard type of sliding gear, operating on the selective principle and giving three forward speeds and one reverse. The differential is placed on a countershaft, final drive to the road wheels being by means of double side chains in accordance with the practice developed in chain-driven pleasure cars of high power. The usual distance rods are employed to bear the stresses of driving and to provide a means of adjusting the chains. Semi-elliptic flat springs are used forward, directly under the motor, to avoid road shocks, while heavier springs are used in the rear. Internal expanding brakes are fitted in drums on the driving wheels. The wheel base is 140 inches, and the wheels, 41½ inches in diameter, giving the vehicle a speed of from 4 miles to 15 miles an hour.

Where desired for road service, four-inch, twin, solid rubber tires may be fitted on the rear and single tires of the same forward. As ordinarily supplied, the wheels are equipped with cast steel rims studded with two-inch hardwood plugs, which make a smooth-tired, silent running wheel which not only meets every requirement of farm service but is also practical on hard roads and paved streets. This makes a wheel of low initial cost as well as one that involves little or no expense for replacements and repairs, the hardwood plugs being very durable. In addition to the construction mentioned, the wheels are also provided with 8-inch extensions in the rear, giving the driving wheels a total face of 14 inches. These extension rims are fitted with nine blades which automatically act the moment the wheels strike soft ground. When this occurs, the blades slide and catch back, penetrating the ground to a depth of 4½ inches, and effectively preventing slip. For work in the field or other soft land, they may be permanently locked in the outward position by a pin, provided for the purpose, or they may be detached altogether by removing a few bolts.

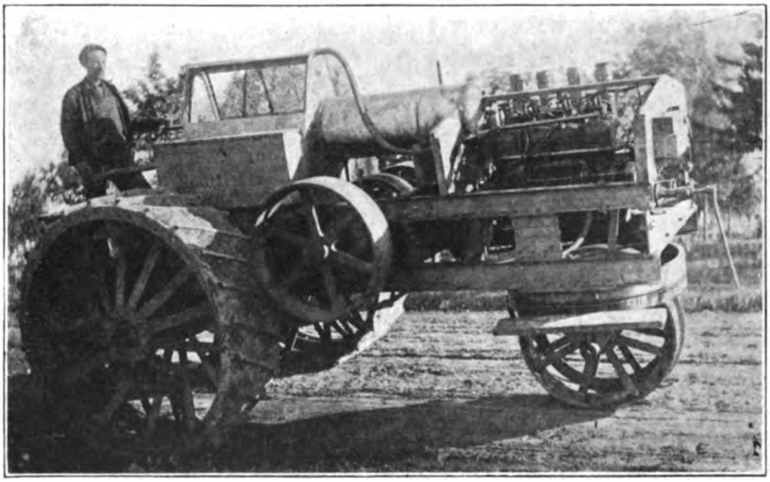


Fig. 82. Brennan Tractor.

As a truck, the Avery tractor has a capacity of three tons and is also capable of hauling one or two loaded trailers behind it; in farm work it will plow eight to ten acres a day, using approximately two gallons of gasoline per acre for ordinary plowing, and moving at a speed two-thirds faster than horses, from which its efficiency in this work, as compared with animal traction, may readily be gauged. For haulage, it may be fitted with bodies designed for the transportation of grain, stock, hay, or the usual stake body for general use, while a pulley attachment is also supplied for driving farm or other machinery.

Brennan. As a type falling between the two general classes described above, may be mentioned the Brennan traction engine, shown in Fig. 82. This is a combination of the features to be found in the former, in that a four-cylinder, vertical, high-speed Brennan motor of the usual automobile type is employed as the power plant, while the construction of the running gear is similar to that of the usual heavy and very slow-moving traction engine. In fact, so far as the latter is concerned, it represents a closer approach to the old steam tractor type than any of those described.

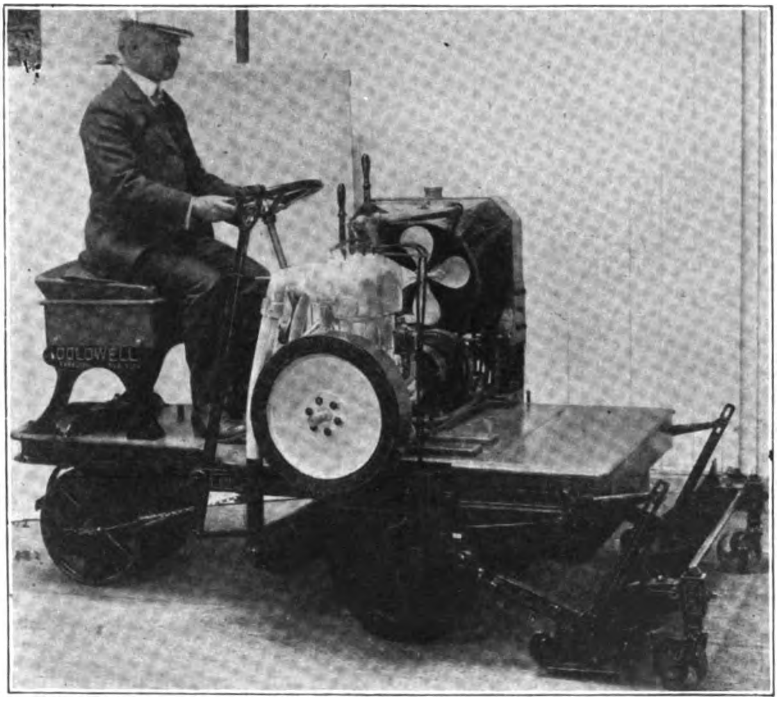


Fig. 83. Coldwell Gasoline-Driven Lawn Mower.

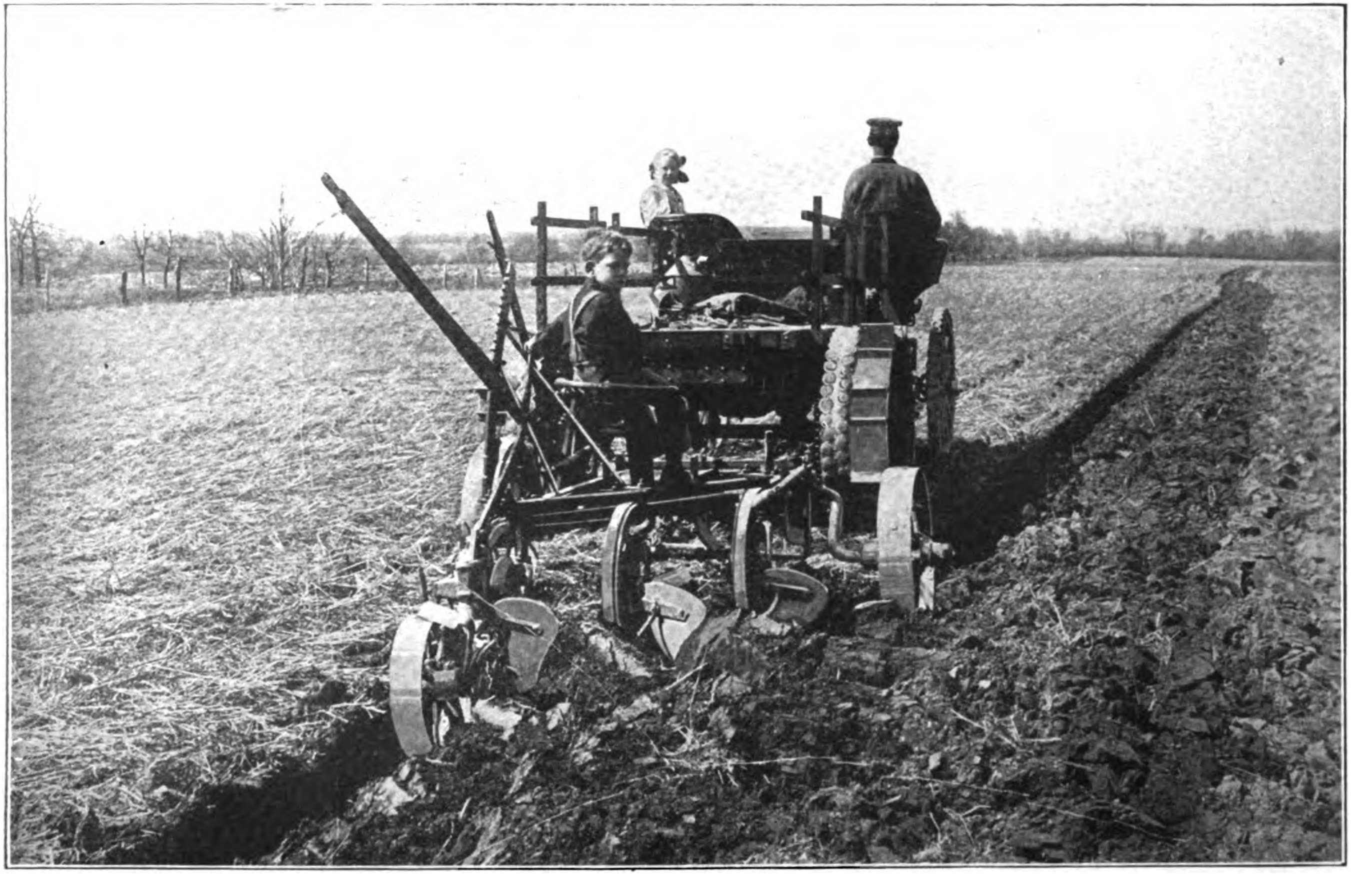


Fig. 84. Avery Tractor Pulling a Gang Plow.

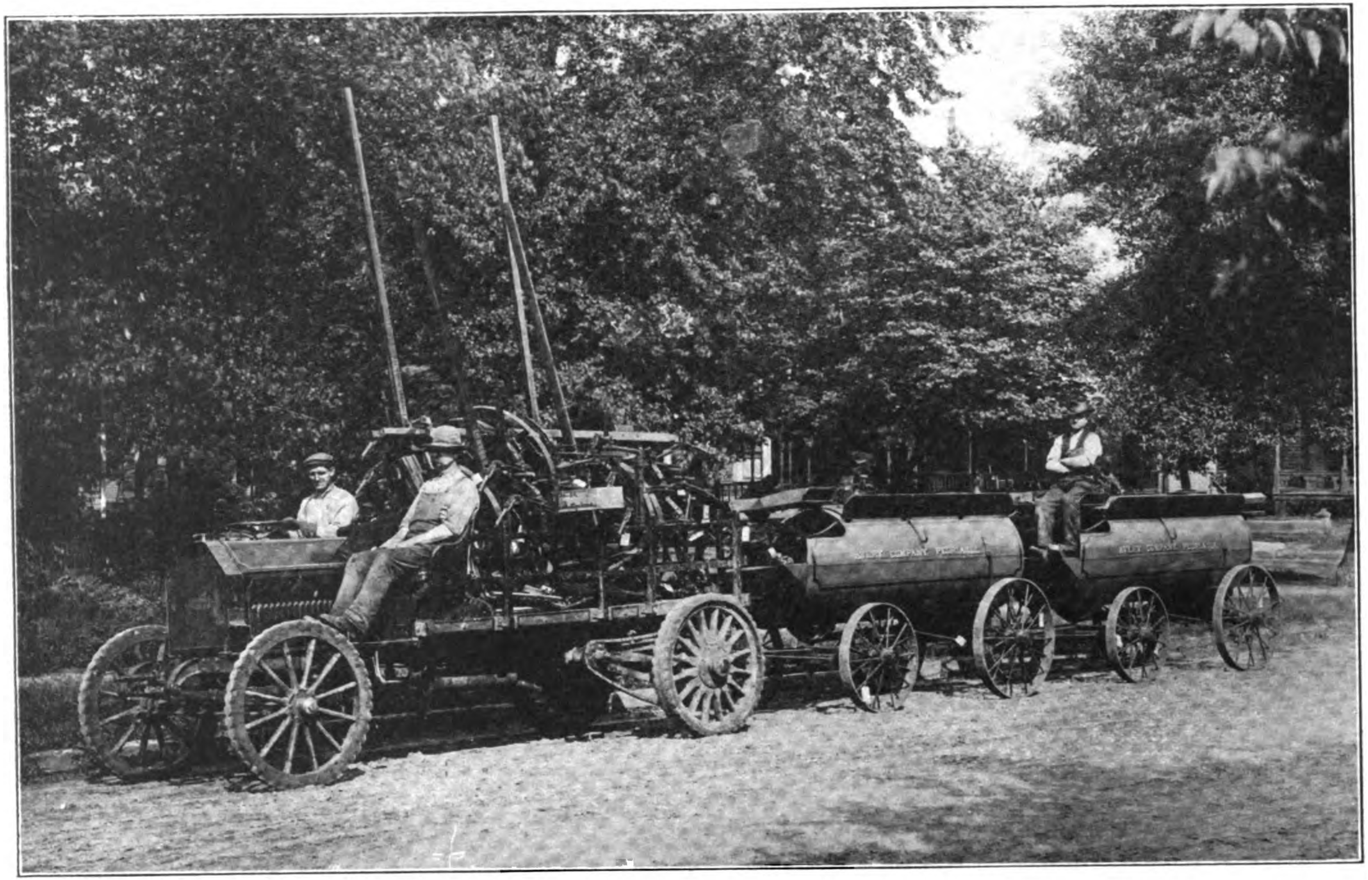


Fig. 85. Avery Tractor on the Road.

Kelly-Springfield. Though designed principally for road rolling, the Kelly-Springfield gasoline-driven road-roller may also be utilized as a traction engine for hauling road material, or for running stone crushers and similar machinery. As weight is an absolute essential in obtaining the maximum compression on the road material to be consolidated, the tractor is of the most substantial construction throughout and no attempt has been made to cut it down by the adoption of a high-speed engine, such as that employed on the Brennan tractor.

Coldwell. The Coldwell gasoline-driven lawn mower, Fig. 83, is a type that does not fall into any of the foregoing classes. Its motive power consists of a two-cylinder, four-cycle, vertical motor, placed transversely on a platform. The drive is through the medium of a planetary gear and a chain. The same makers also build lawn mowers with one- and two-cylinder, two-cycle motors.

Generally speaking, the types of vehicles already described suffice to complete the range of those ordinarily employed for agricultural and similar service, and from the accompanying illustrations one may gain an idea not only of the varied character of their usefulness in such operations as plowing, threshing, road-building, and haulage, but likewise the effective manner in which the work is performed at a greatly reduced cost. Fig. 84 illustrates an Avery tractor at work in the field, while Fig. 85 shows it on the road, carrying and hauling a load.

ROAD TRAINS FOR HEAVY HAULAGE

It will be apparent from a study of the design of both the electric and gasoline trucks that there is a more or less sharply defined limit to the capacity which these vehicles may not exceed and still be commercially practical. This is lower in the case of the electric than the gasoline truck, for obvious reasons, and the fact that the former has seldom been built to carry more than five tons would seem to place this figure as its permissible maximum. As a matter of fact, it is better adapted for carrying loads up to and including three tons, than above this weight. The gasoline truck is naturally not limited as to power, but, as has been pointed out, difficulty has been encountered in the design of a suitable tire for weights much in excess of five tons, and it will be noted that up to the present writing, but one American manufacturer has attempted the design and construction of a 10-ton truck.

It is not difficult to realize that there are numerous reasons which make a load of ten tons about the maximum which can be practically transported on a commercial scale in a single vehicle, regardless of the type of power-plant employed to move it. The first of these reasons would naturally be the excessive dimensions of the body and wheel base necessary to accommodate a greater weight in the form of anything but the very heaviest classes of merchandise, and making the vehicle as a whole so unwieldy that it could not be handled in traffic. Not alone because of its enormous size, but likewise because of the excessive pressure per square inch to which its wheels would subject pavements, bridges, and manhole covers, it would undoubtedly be barred from using the streets in the average municipality. The amount invested in such a large unit would be considerable and the loss arising from having to withdraw it from service for repairs would be correspondingly heavy. For this reason it will be seen that there are other matters beside those of design which operate to restrict the size of a vehicle. Many manufacturers have not considered the building of trucks above 5-ton capacity commercially practical, as whenever large quantities of heavy merchandise are to be transported, it is preferable, for the reasons cited, to move it in units not exceeding this size, rather than to attempt to carry greater amounts at one time. On the other hand, the investment involved in the purchase and the expense of maintenance of a number of such trucks would frequently be so large as to be unjustifiable for the transportation of comparatively cheap material. Sand, bricks, iron ore, low-bearing gold ore, and similar materials may be cited as instances.

The road train solves the difficulties mentioned above in a satisfactory way. A horse that is only capable of carrying a few hundred pounds on its back, can haul many times that load in a wagon; and so too a 5-ton truck is able not only to carry its own load, but haul a trailer bearing an equal weight at the same time. Practically the only difference in such a case would be the amount of fuel required and the slower speed at which the double load could be moved. To go back to the single large truck for a moment, another objection is to be found in its inability to exert sufficient tractive effort under all conditions of loading and road surface. One expedient adopted to overcome this has taken the form of a four-wheel drive, examples of which have been given on Page 37 and Page 123. But this necessitates expensive complication of the propelling and steering mechanism, with the extra weight of these parts assisting depreciation. To overcome these disadvantages, six-wheeled vehicles have been tried, but it will be evident that unless more than one pair of wheels is driven, the traction disadvantages of the ordinary two-wheel drive are always present, and the six-wheelers in question have always been designed to utilize the third pair as the drivers, with most of the dead load borne by the other four. The complication, inseparable from this arrangement, detracts seriously from its commercial practicability, not to mention the greatly increased initial cost and expense for maintenance. It is therefore doubtful if the six-wheel vehicle will ever be seen in any great numbers.

The numerous difficulties to be overcome would appear to make the traction engine and trailers, the only practical solution of the problem. To an extent, this method is employed in the United States with the old style steam tractors as the motive power, but in the light of modern developments, the speeds attainable by this method are too slow. In England and on the Continent, where speed does not appear to be quite as much of an object as in this country, tractors have been largely employed From an engineering point of view, the objectionable feature of having but a single pair of driving wheels, counts seriously against the system. Only the fact that roads are very much better abroad than in this country has made its adoption on any scale commercially possible. Here, unless the driving wheels were fitted with cleats to assist propulsion, it would be impossible, at times, to haul a paying load at all, and even with cleats this could not be done if the road had deep sand or mud on it. The use of cleats or similar traction devices is objectionable in road work, because they concentrate the load of the driving wheels on comparatively small areas of the road surface, causing rapid deterioration.

Renard System. The first practical attempt to eliminate the shortcomings of the ordinary traction system was made by Colonel Renard, who developed the road-train system which bears his name. This consists of several vehicles coupled together, the first one of which carries the power-generating, speed controlling, and steering apparatus. A shaft, arranged with the proper number of universal and slip joints extends throughout the length of the train and transmits the power for propulsion to the driving wheels of each vehicle. It is accordingly possible to transport a large and well-paying load without having excessively heavy individual units, which are subject to rapid depreciation due to the inability to provide sufficiently resilient tires, or sufficiently strong wheels or springs for heavy loads. The road surface is also protected as the distribution of the weight over the greater number of wheels and, therefore, on a correspondingly greater area, does not make the unit load any heavier than where a single vehicle is employed. In addition, rubber tires are not necessary as sufficient tractive effort is obtained by the increased number of propelling members. Steel tires may be used on the trailers, since they carry no mechanism other than the comparatively simple driving and steering apparatus mounted on them, while rubber tires are permissible on the leader, or power-wagon, because in no case would it be found necessary to have the weight of this exceed what has been found practicable in independent units, in fact, it need not be above 3 to 4 tons.

The chief disadvantage of the Renard system lies in the application of power throughout the train by mechanical methods. This involves the employment of a large number of universal joints, and it is a matter of common knowledge that their efficiency is directly proportional to the angle at which they must transmit the power. Owing to variation in the road surface, this would always be considerable even where the train was moving straight ahead, reaching a maximum in rounding curves of short radius. In other words, much too large a fraction of the total power developed by the leading vehicle is wasted in the linkage between it and the driving wheels of the various trailers; the actual driving mechanism of the latter also contributes to the power loss in a greater degree than where electricity is employed for this purpose.

Sampson Train. These considerations led to the construction of the Sampson motor road train, which was exhibited for the first time two years ago at the automobile show in New York. Though designed along the same general lines as the Renard train, it really combines engineering features that are the outgrowth of motor-car and electric-railway practice. Its chief advantage naturally lies in the employment of electricity as the motive power, owing to its far greater flexibility. It is, in brief, a Renard train with a multiple-unit, electric control system, such as is now employed on thousands of elevated and subway trains in urban railway service. On the usual type of gasoline truck, 40-horse-power is not considered more than sufficient to move a load of 3 to 5 tons, and many vehicles of the latter capacity are equipped with 60-horse-power motors. In the Sampson road train, a 40-horse-power motor develops sufficient energy to transport 14 to 20 tons, according to the number of trailers employed. Every car is self-propelled, just as every other car in an elevated or underground train is a "motor car," the entire train being controlled by the motorman in the box of the first. But as the motor road train has no outside source of energy such as the third rail or trolley wire, each vehicle must derive its power from the tractor. It has already been pointed out how this is accomplished mechanically in the Renard train.

Motor. The source of power in the Sampson train is a four-cylinder, vertical, four-cycle gasoline motor of the type usually employed on the gasoline-driven truck, but instead of transmitting its power through numerous and constantly changing angles by positive mechanical means, perfect flexibility is attained by first converting it into electricity and transmitting this through heavily insulated cables to the motors on each of the trailers. The motor is accordingly coupled by means of a heavy, Morse silent type of chain to the armature shaft of a multipolar electric generator placed in front of it and directly behind the radiator. The voltage at which the current is supplied may be varied through a range which insures that the full current capacity of all the motors is within that of the generator. The current is controlled on the series-multiple system by a rotary switch interlocked with the starting rheostat so as to make it impossible for the driver of the train to accidentally damage any of the apparatus. This switch is operated by a second wheel mounted on the steering pillar, just below the steering wheel, which not only actuates the steering gear of the leading vehicle, but also that of all the trailers, causing their wheels to track almost exactly with those of the first car.

Switches are also provided so that the train may be hauled by the motors of the tractors alone; or one or more of the trailers may be operated while the leading car is standing still. The power-plant, including the radiator, is mounted on a subframe, suspended from the main frame by springs, to relieve it from torsional stresses and to prevent damage from vibration and jolting due to the employment of steel tires. Each car has six wheels, the intermediate pair being of a larger diameter than the other four and acting as the drivers. They carry a predetermined proportion of the entire weight borne by the trailer and measure 54 inches in diameter; they are fitted with steel tires of a width to suit the conditions. Two independent electric motors on each car drive these wheels through a reduction gear. The motors are spring suspended and are particularly designed not only to stand heavy overloads, but also to be proof against the roughest kind of usage. They are back geared, through pinions running in an oil bath, to jack shafts carrying sprockets on their outer ends, from which the final drive is taken by means of 1¾-inch pitch roller chains. As each driving wheel is thus driven independently and is free to rotate at any speed imposed upon it by the conditions, regardless of the others, there is no need for differential gearing, while the electrical transmission of the power eliminates the usual

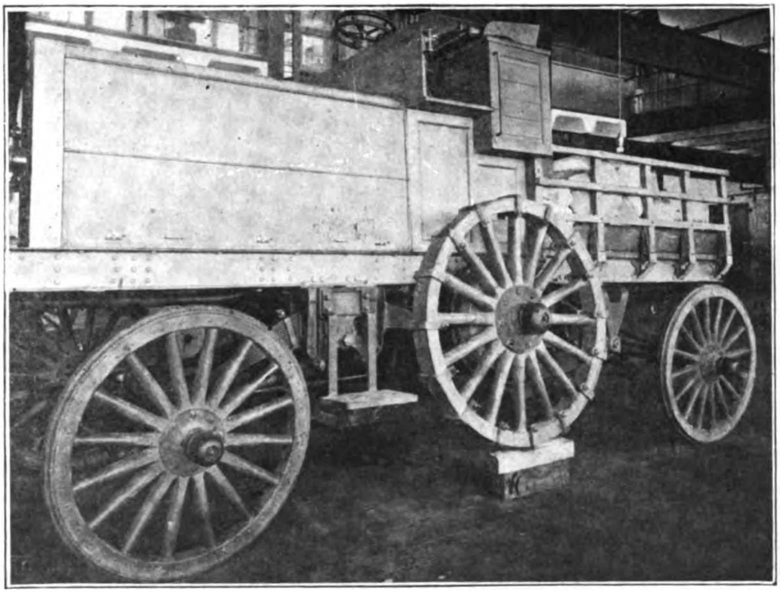


Fig. 86. Sampson Power Wagon.

sliding change-speed gear and driving shafts. These driving wheels are fitted with cleats which are provided in order to secure ample traction with steel tires, and the suspension is of such design that the wheels may ride over all sorts of obstacles with impunity, as is well illustrated by Fig. 86.

Steering System. One of the features which makes the use of the Sampson train possible in the rough country in which it is designed to operate, is the inter-connected system of steering already touched upon. Though apparently very unwieldy, one of these 14-ton trains can negotiate a corner that is beyond the average touring car—in fact, even beyond the taxicab whose steering gear is specially designed with the requirements of city traffic in view. In fact, one of these heavy trains can easily get around a corner which was only possible for the six-foot-wheel-base runabouts of several years ago. The extremely sharp turns that can be negotiated are strikingly illustrated in Fig. 87, in which the tractor and the last trailer are going in almost diametrically opposite directions at the same time. When in New York a few years ago, the writer saw a train turn a corner in a narrow street with its wheels within six inches of the curb, while the wheels of the last trailer came less than two inches nearer to the curb at the same point.

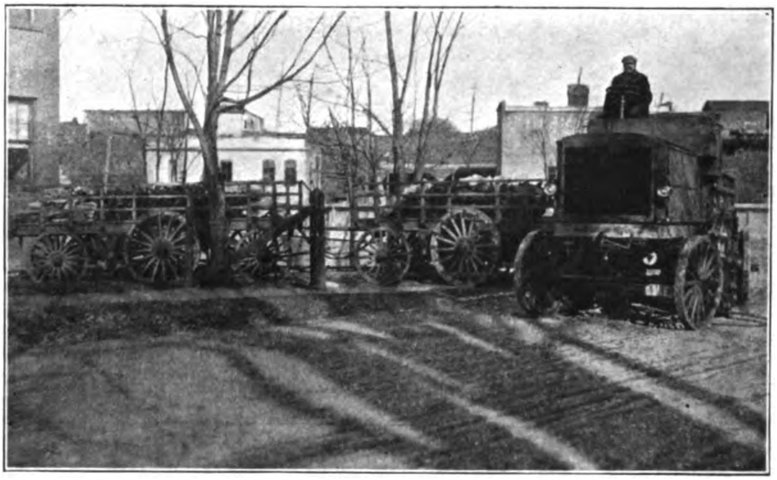


Fig. 87. Sampson Road Train Making a Sharp Turn.

This result is obtained by not only utilizing the front and rear wheels of every one of the cars as steering wheels, and connecting the steering tongue of one car to the one preceding it, but also by cross-connecting the front and rear pairs of wheels of each vehicle, all being mounted on steering knuckles as in automobile practice. The connecting rods of the steering gear are equipped with universal joints and are supported at the center, the joints relieving the rods of the strains due to the changing positions of the front and rear axles as the car moves over uneven ground. The driver, sitting on the tractor, controls the whole train by means of the usual hand steering wheel and an irreversible gear connected with the front pair of steering knuckles of the tractor. By means of the cross-connecting rods underneath, the rear pair of wheels is turned in the opposite direction to the front pair through precisely the same angle, thus giving the entire car a pivotal motion on the central pair of driving wheels. This carries the rear end to the outside of the circle, so that the rear wheels, instead of cutting inside of the track of the forward ones, follow the same path.

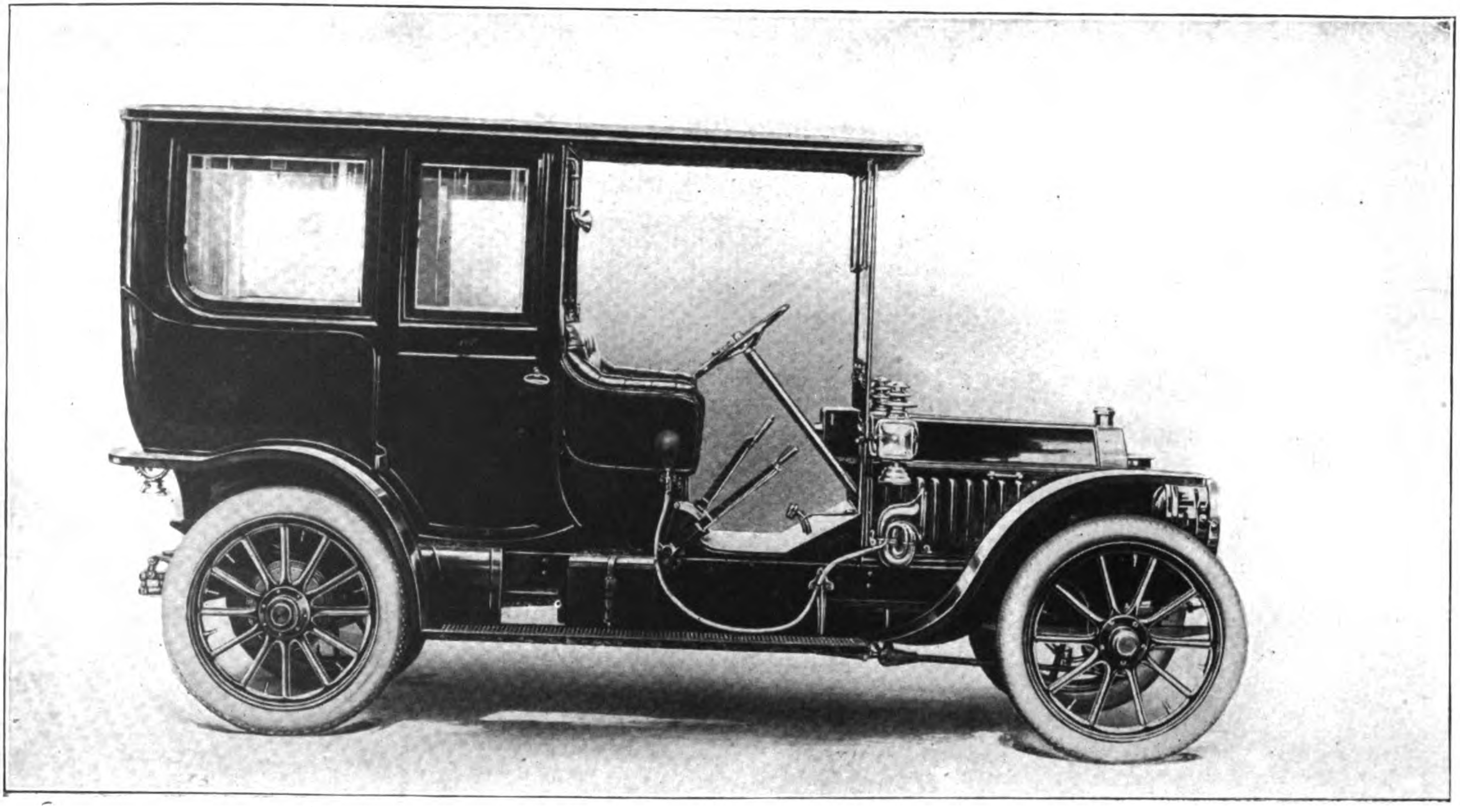
The method of connecting the steering of the tractor with that of the trailers will be understood when it is borne in mind that all are "double-enders," *i. e.*, alike at both ends so far as the possibility of connecting them together is concerned. A yoke, bolted to the axle at the center is also fastened to the tie rod that connects the steering knuckle arms. In the slots at the ends of this yoke is bolted a forked steel tongue, in the free end of which is an eye, or hole. This fork is at the rear end of the tractor and by means of the eye and an eye-bolt it is connected to a similar fork protruding beyond the front end of the first trailer; this construction is similar in many respects to the old link-and-pin coupler of steam railway practice, except that the eye-bolt is clamped to a horizontal rod that is free to slide in a metal frame, bolted to the under side of the car, and the bolt to which the tongue is attached projects downward, through a slot in this frame, sufficiently to permit of considerable lateral movement. This motion is cushioned, however, by placing a coiled spring under compression at either side of the rod, to avoid the shocks that would otherwise be transmitted to the steering gear.

It will be readily understood that, owing to the opposite angles which the steering wheels of the tractor, or leading car, assume when making a short turn, the rear end swings out as the front end swings in, exactly as when a long street car goes round a corner the front and rear trucks assume opposite angles. The outward swing carries the front end of the tongue of the trailer in the same direction it had been moving, up to a certain point, when it is suddenly deflected in the new direction. As the tongue moves, it changes the angles of the four steering wheels of the trailer. Thus, the front of the first trailer begins to make the turn at practically the same point as the tractor did, while the rear end swings outward, continuing the second trailer in the original direction. With this construction, the entire train, measuring 60 feet in length, can be turned in a circle having a radius of 20 feet, measured outside the hubs. The operation of steering is as easy as that of a 5 ton truck and the control is so simple that one man can operate the whole train with ease.

Drawbars are used between the trailers, their principal function being to equalize the distance between the several units of the train and to equalize traction. The torque is so evenly distributed throughout the train, however, that it has been found possible to walk between the trailers and pull out any one of the drawbar pins while the train was climbing a 11 per cent grade under load.

Brakes. Braking is effected electrically through the motors themselves under ordinary conditions by adjusting the controller at a point which provides a braking effort equivalent to the capacity of the motors. The electrical braking system operates smoothly and is easy to handle. For emergency purposes and for service in very hilly country, each of the driving wheels is equipped with a powerful, expanding-band brake operating against the face of the sprocket drum. Those on the tractor are set by means of a hand wheel just below the steering wheel, while those on the following cars are operated by a wheel attached to the side of the frame and must be manipulated by an assistant on the trailer. With the exception of these emergency brakes, the entire control of the train is concentrated in the hands of the driver, who rides on the tractor.

To facilitate making up the train and maneuvering in small yards or other confined spaces, both the tractor as well as all the trailers are made double-ended, and any of them can be connected up and run either end foremost with equal facility. Sockets, similar to those employed for charging electric vehicles, are provided at both



FOUR-CYLINDER LIMOUSINE
Peerless Motor-Car Company, Cleveland, Ohio.

ends, into which plugs on the end of the connecting electric cables may be inserted. By using long connecting cables, the trailers may be moved about freely while the tractor itself is standing still. Although all the driving wheels are provided with cleat-equipped steel tires, solid rubber tires may be employed where the conditions are such as to warrant their use, though the steel-tire equipment has been found to provide all the tractive effort that is necessary.

The tractor itself, Fig. 88, has a carrying capacity of 2 to 3 tons, in addition to transporting the power plant, which is placed under a huge bonnet forward, as in automobile practice. Each trailer can carry 6 to 8 tons, the dimensions of the loading platforms being 17 feet by 4 feet 2 inches. The bodies are carried on four extra long, semi-elliptic springs, which are pivoted and guided in pedestals, giving them the functions of equalizing beams to distribute the load uniformly on the three axles, no matter how rough and uneven the road may be, and of maintaining the axles in correct transverse position, relative to the body. Distance rods hold the axles against fore and aft displacement, the ends of the springs merely resting in pockets on the axles and thus contributing greatly to the flexibility. A speed of six miles an hour can be attained on the level with a load of 20 tons, this being based on a hard macadam road. On level dirt roads, this would be reduced to 5 miles an hour, and to 2 miles on a ten per cent grade with a good road surface.

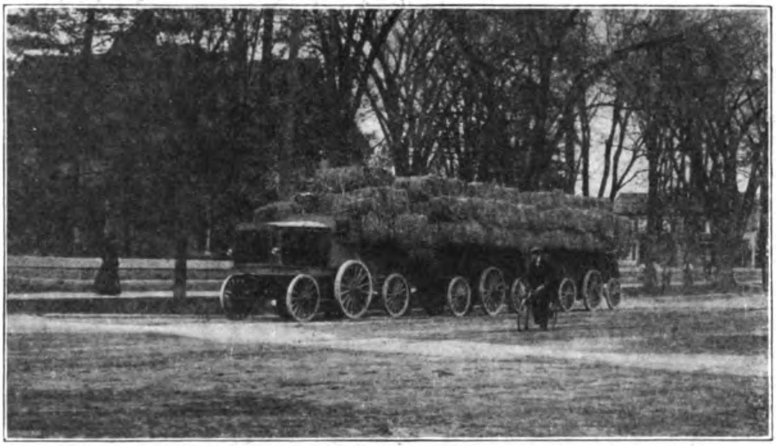


Fig. 88. Sampson Motor Road Train in Service.

Gibbs Train. Another American road train was the Gibbs and while it is no longer built, so far as the writer is aware, its design is of interest, not alone as showing the tendency in this direction, but also because Gibbs trains have been in use in the West. The first Gibbs train consisted of a power wagon and two trailers, the motive power being a three-cylinder, vertical gasoline engine, direct connected to an electric generator furnishing power to motors on the trailers. These trailers were practically nothing more than heavy trucks built on lines that have become familiar through years of usage in wagon building. The front wheels was small, in order to turn under the body, while the rear ones were almost twice their size. In both cases, they were carried directly on the axle, and the entire front axle of each of the trailers was swiveled for the steering, instead of the wheels being mounted on steering knuckles, as has become standard practice in automobile design. They were interconnected so as to be steered from the tractor, but as only two wheels on each vehicle could be turned, the train was naturally not capable of rounding as sharp a turn as the Sampson train.

The tractor itself took the form of a road locomotive, being protected by a cab similar to those employed on electric locomotives, and was not designed to carry any part of the load. Its wheels were of comparatively small diameter and were shod with solid rubber tires, while those of the trailers were of steel. The speed of the train was regulated by a two-motor, railway type of controller so modified that by operating the drum intended for reversing the car motors, the vehicle motors would be connected in series or multiple combination. The motors themselves were of the standard series-wound type ordinarily employed in electric automobiles. The main drum of the controller was employed to cut resistance in or out of the motor circuit. No provision was made for reversing the trailers as they were only designed to run in one direction; separate switches on the tractor, however, made it possible to drive the latter in either direction.

The second Gibbs train consisted of a power wagon hauling four trailers, the former having as its power-plant two, three-cylinder, gasoline engines driving a double-commutator electric generator through positive clutches on the engine shafts and Morse silent chains. The rear wheels of all the trailers, which were four-wheelers, were driven by series motors through reducing gearing and roller chains. The road wheels in this case were of special construction, consisting of steel disks flanged at the circumference. These disks were solidly riveted to bronze-bushed steel hubs and carried steel tires eight inches in width. Speed regulation was accomplished by the same type of electric controller employed on the first train, except that the controller drum generally used for reversing the car motors was in this case utilized to connect the two windings on the armature of the generator in series or parallel, while the main drum of the controller cut resistance in or out of the main motor circuit. Each vehicle had an independent switch for reversing the motors. This train was employed to transport machinery and supplies from the railroad station to a mine in Arizona, the trip being 115 miles each way, the route leading through a desert and mountainous country, entirely guiltless of roads according to the usually accepted definition of the term.

It is for service of this nature that the road train is particularly adapted and as there are many localities in this country and Mexico where the demand for transportation to and from mines situated at long distances from the railroad is active, but where the traffic would not warrant the building of a railway line for many years to come, there will doubtless be considerable need for heavy road trains of the gasoline-electric type. The question may doubtless occur to the thoughtful person why the ordinary heavy truck, say of 5-ton capacity, would not fill the requirements equally well, particularly as it would be capable of greater speed than the train. It will be recalled, however, that mention has been made of the fact that no more power is required to move 14 to 20 tons load on a train, than is needed to propel the average 3-ton to 5-ton truck, while under the extremely adverse road conditions found in districts where trains are now employed, the speed of the single vehicle would doubtless not exceed the average of the multiple unit. But the most important factor would be the increased cost of fuel and labor, as in the Far West and Southwest, fuel is one of the most expensive items. The labor cost would be increased in exactly the ratio that the number of independent units was added to, as in place of the single driver needed for a tractor and five trailers, five drivers would be required. By purchasing a second motor for the tractor, a second armature for the generator, and adding a stock of such other replacement parts of the power-plant and mechanism of the vehicles as are most apt to give out in service, there is no reason why one of these road trains should not prove very efficient and reliable.

SPECIAL TYPES

Where both speed and ability to transport heavy loads with great rapidity are essential, the gasoline-propelled vehicle is naturally much the superior, not only of other types of power wagons, but also of the horse. The most important service in which these qualities may be utilized to the greatest advantage, is naturally that of fire protection, and a large number of automobiles of one type or another are in use for this purpose the country over. Those first adopted were naturally nothing more than touring cars, used to enable fire-department officials to arrive on the scene in advance, in order to most effectively direct the placing of the slower horse-drawn apparatus. Then came the addition to the touring car of the lighter forms of fire-fighting apparatus, such as chemical tanks and the like, and later in its order came the power-driven, chemical fire engine, which was nothing more or less than a high-powered, touring-car chassis fitted with the apparatus necessary to enable it to assume this rôle. In its turn there has been developed the fire patrol wagon, carrying the equipment needed to protect the contents of burning buildings, so that by successive stages every function of the fire-department service formerly carried out by horse-drawn apparatus, has been usurped by the power-driven vehicle. This process of development culminated a year or two ago by the ordering of a specially designed hose wagon for the new high-pressure service of the largest city in the country. The vehicle supplied, Fig. 89, was built by the makers of the Knox cars.

In every case, the chief difference between these special vehicles and the types of trucks already described lies mainly in their equipment, with certain modifications of the chassis to meet the changed conditions; it will, therefore, only be necessary to give a sufficiently detailed description to permit of the identification of the chassis as one of the types already previously dwelt upon. New York's special, high-pressure service wagon, has as its foundation a chassis of one of the Knox 8,000-pound trucks. This is equipped

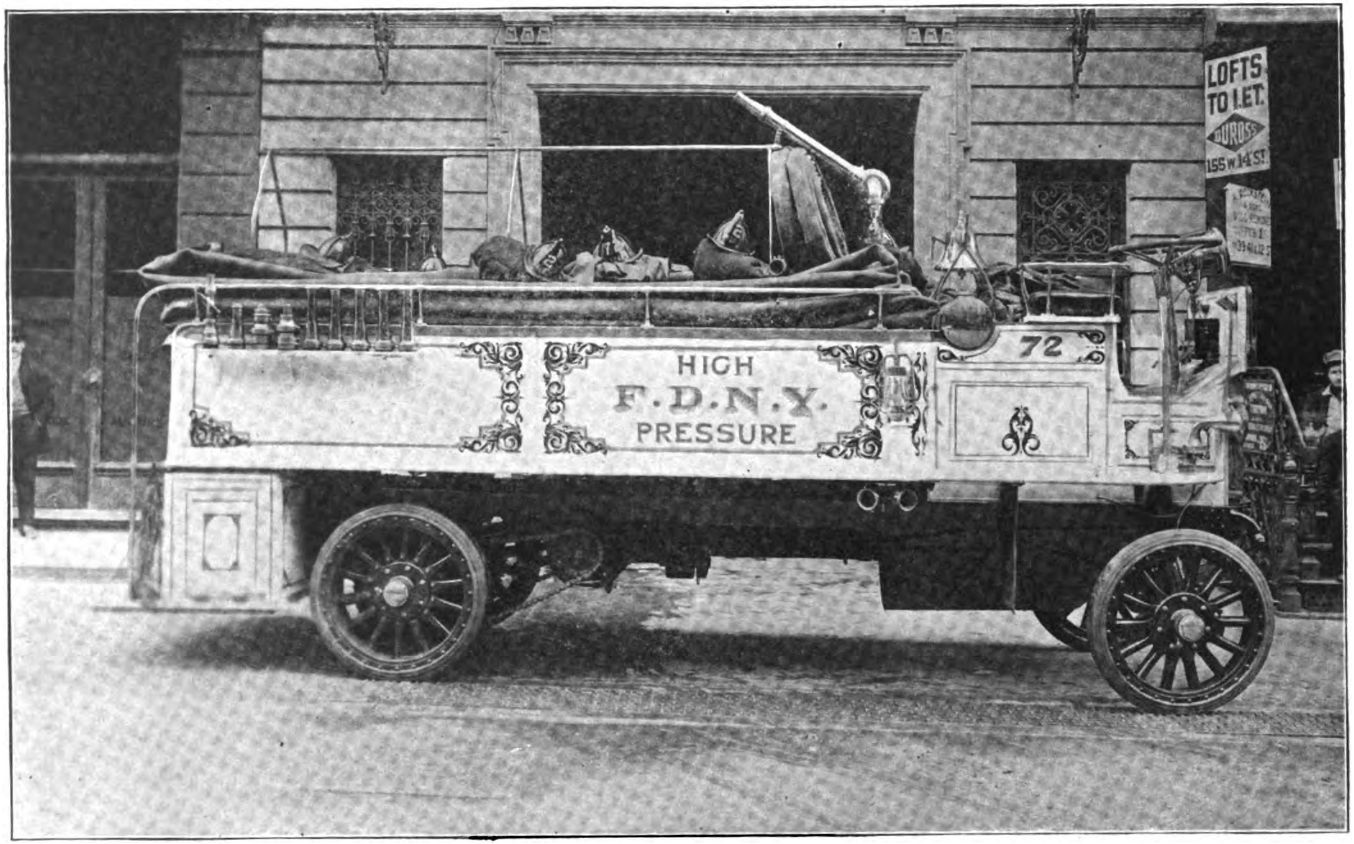


Fig. 89. Knox High-Pressure Hose Wagon.

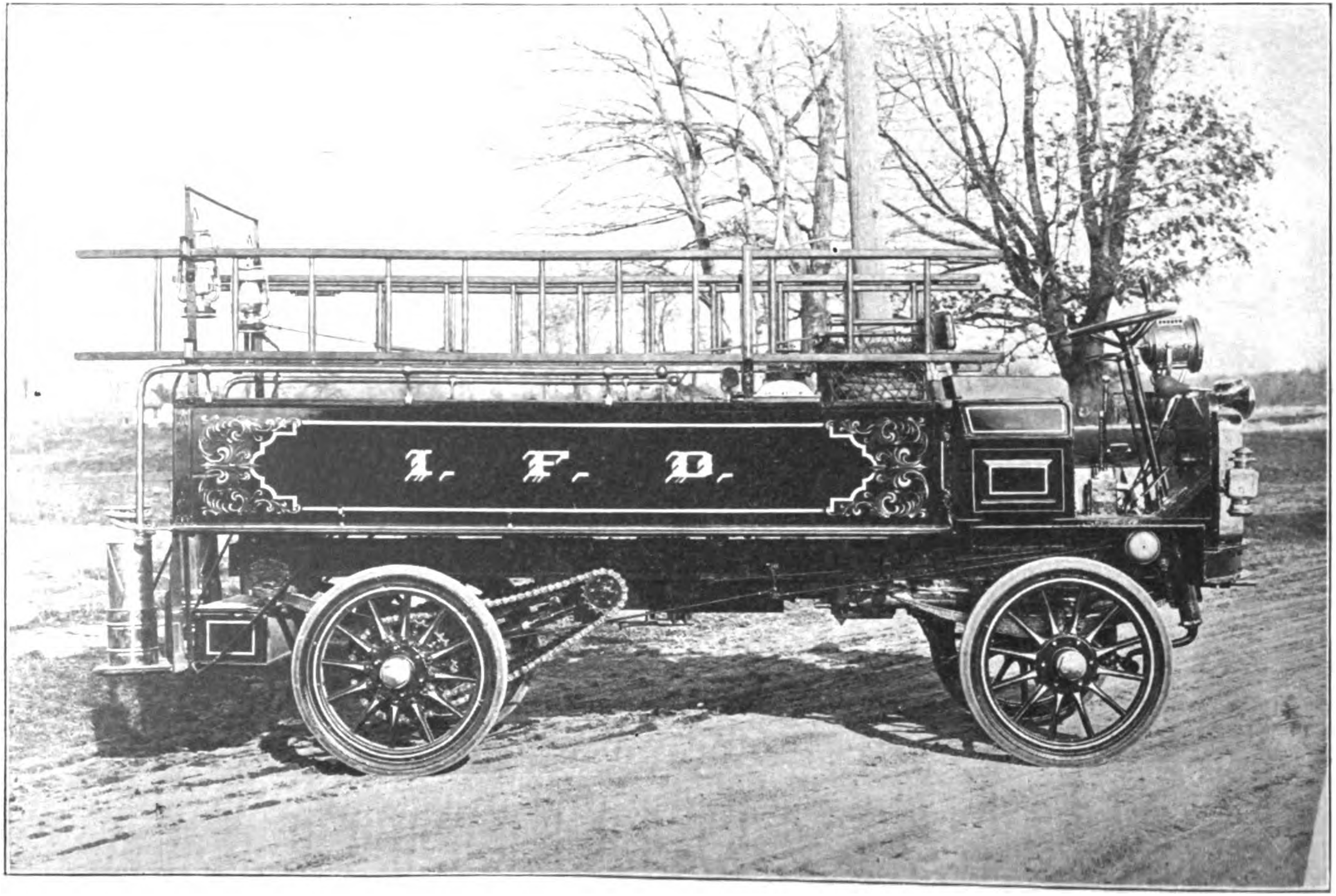


Fig. 90. Knox Fire Wagon.

with a 40-horse-power, four-cylinder, vertical motor, with 5-inch by 4¾-inch cylinders of the water-cooled type, and a special, heavy, three-speed transmission of sliding-gear pattern such as is employed on all the heavier Knox water-cooled commercial cars. The wheel base is 149 inches and the tire equipment consists of 36-inch by 4-inch single, solid rubber tires forward, and dual tires of the same dimensions on the driving wheels. The chassis weighs 5,400 pounds and its capacity of 8,000 pounds load, brings it up to approximately the total of 14,000 pounds which this most modern of fire-fighting vehicles weighs with its full equipment of high-pressure hose, tools, and uniforms. In addition to these it will be noted that it is also equipped to be used as a stand pipe for the hose; and as a brass nozzle coupled to a length of 3-inch hose with 300 pounds pressure to the square inch is an extremely difficult and dangerous thing to handle, it has proved invaluable in this rôle.

A less pretentious type of fire-fighting motor wagon, intended for suburban service and now in use in New England, is shown in Fig. 90; it consists of one of the Knox 4,000-pound truck chassis with the body equipment as shown. It employs the same 40-horse-power, water-cooled motor as the heavier car, but with a regular type of three-speed sliding-gear transmission. Its wheel base is 103 inches and its tire equipment consists of 34-inch by 4-inch single solid tires in front, and 34-inch by 5-inch solid tires on the driving wheels. An intermediate type of fire-fighting machine, in which speed is one of the chief essentials, is shown in Fig. 91. This car was built for the town of Brookline, Mass., where it has been doing effective service for some time past. Its chassis is also one of the Knox 4,000-pound type, but it is equipped with a 5½-inch by 5½-inch motor developing 48 horse-power and has an extra heavy three-speed, sliding-gear transmission. It has a wheel base of 145 inches and is fitted with the largest pneumatic tires in everyday service, viz, 40-inch by 6 inch, because the combined weight of the chassis and its load carrying capacity—which are equally divided, giving it an efficiency of 100 per cent—is 8,000 pounds.

A most completely equipped, chemical fire engine of the high-speed type employed in the fire-department service of the city of Waterbury, Conn., is shown in Fig. 92. It has a 40-horse-power chain-driven Locomobile chassis equipped with a four-speed, selec-

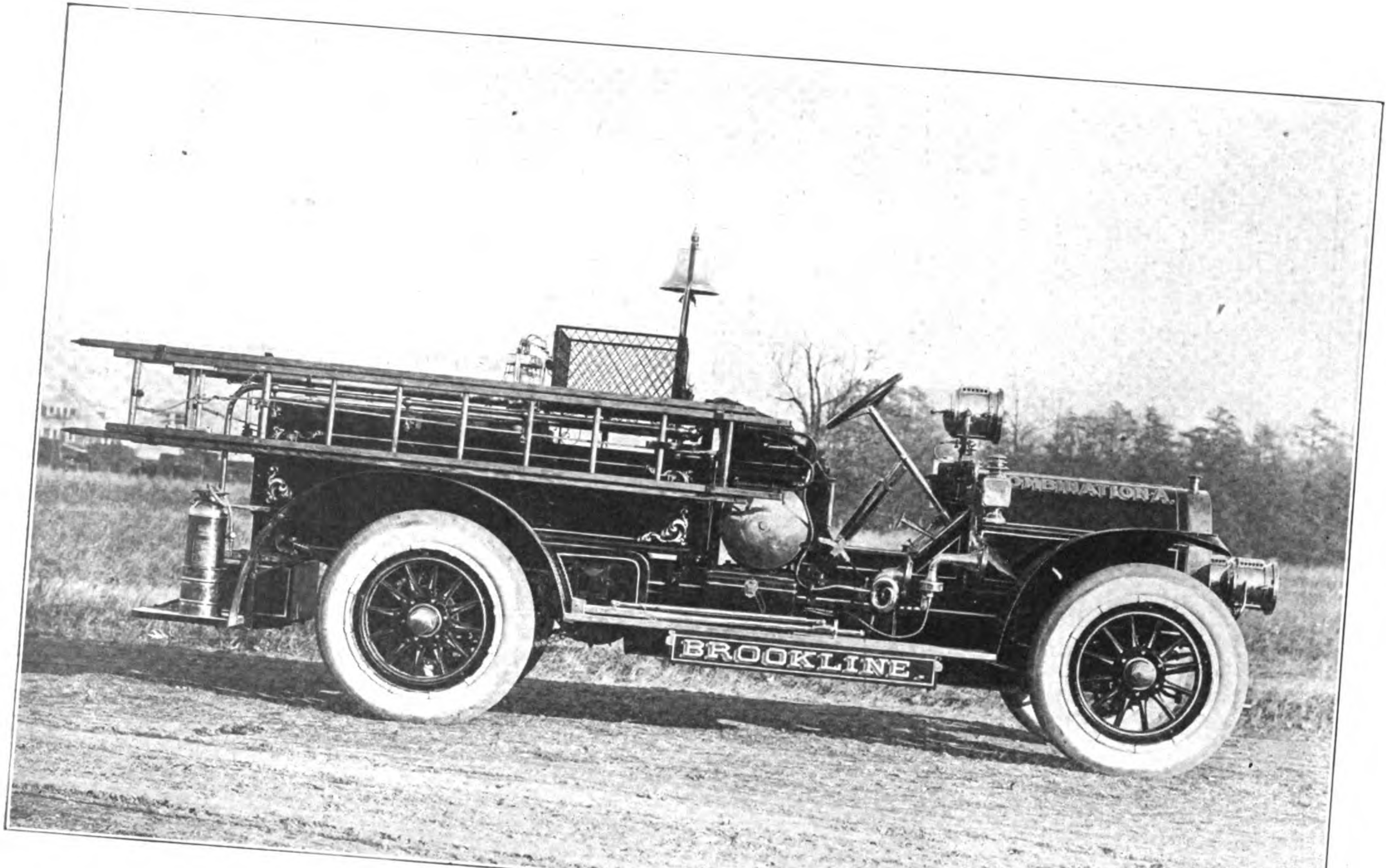


Fig. 91. Knox Fire Wagon.

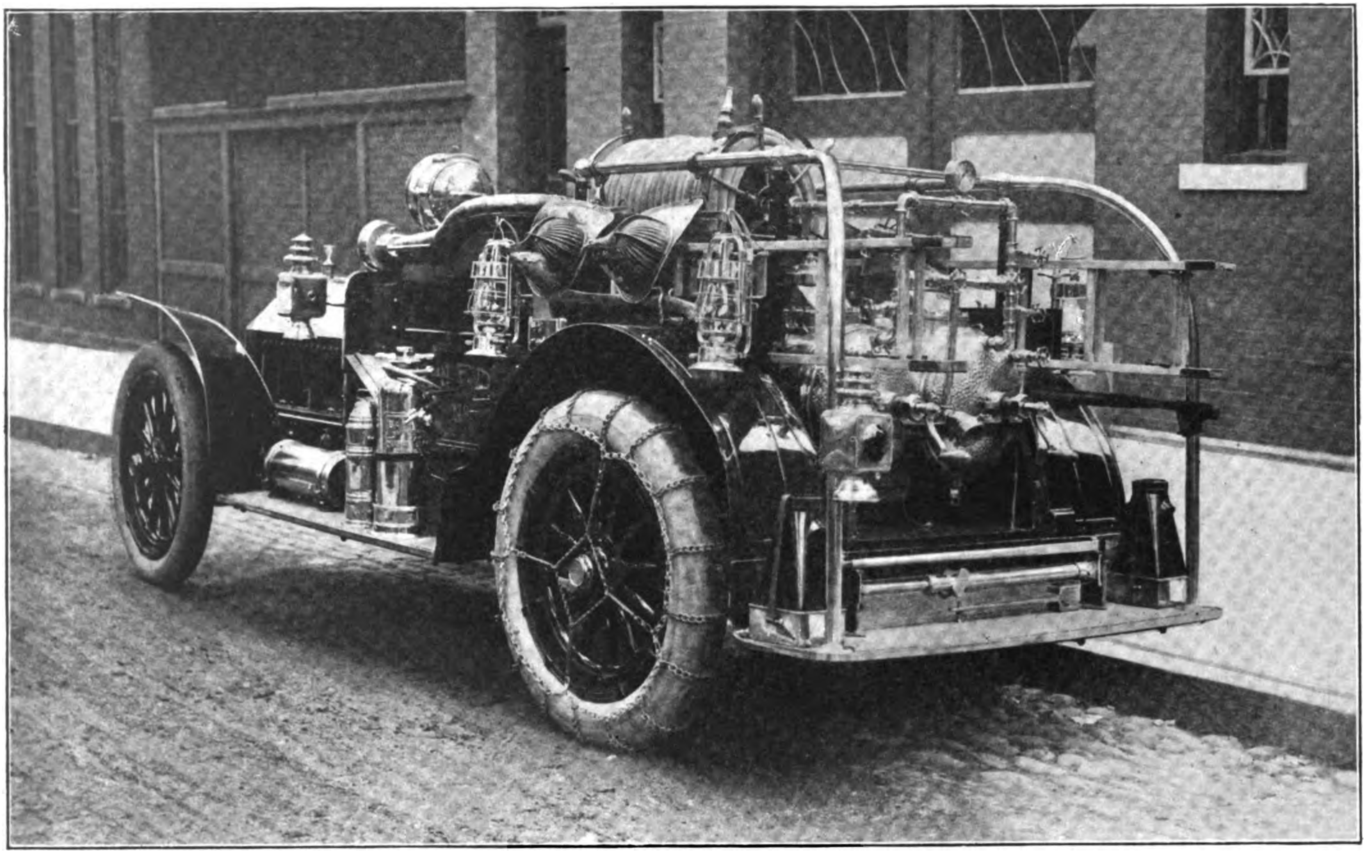


Fig. 92. Locomobile Chemical Outfit.

tively operated, sliding gearset. It carries a large chemical engine designed to be operated by hand, a reel of hose, and the other usual fittings, and has a large acetylene searchlight for use in night fire-fighting as well as driving. It is fitted with pneumatic tires, the rear tires measuring 40 inches by 6 inches.

To attempt to describe all the special types of gasoline vehicles built would involve a reference to practically every form of horse-drawn vehicle that has ever been constructed, besides many more, as the power wagon lends itself to special forms of service to much better advantage than its predecessor, as illustrated by Fig. 93, which is a Knox self-dumping contractor's wagon. This is a medium capacity truck chassis equipped with a two-cylinder, horizontal, opposed, air-cooled engine driving through a two-speed planetary gearset to a countershaft by single chain. From the countershaft the usual double side-chain drive is taken to the rear wheels. Interest naturally centers in the self-dumping mechanism, which is shown in action in Fig. 94. This consists of a countershaft attached to the upper side of the frame and driven from the motor by a single short chain through sprockets giving a speed reduction of about 2½ to one. This shaft is thrown into action by the right-hand lever illustrated. At its center it carries two small bevel pinions arranged to be slid in or out of mesh with a larger bevel gear attached to a long threaded shaft, giving a second speed reduction in about the same ratio. Two

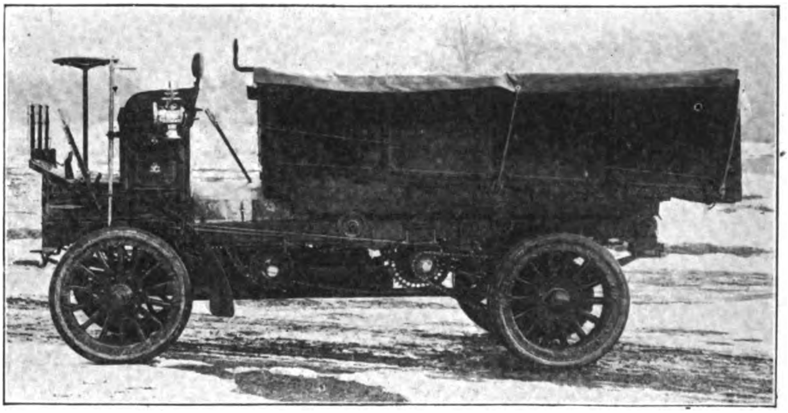


Fig. 93. Knox Self-Dumping Contractor's Wagon.

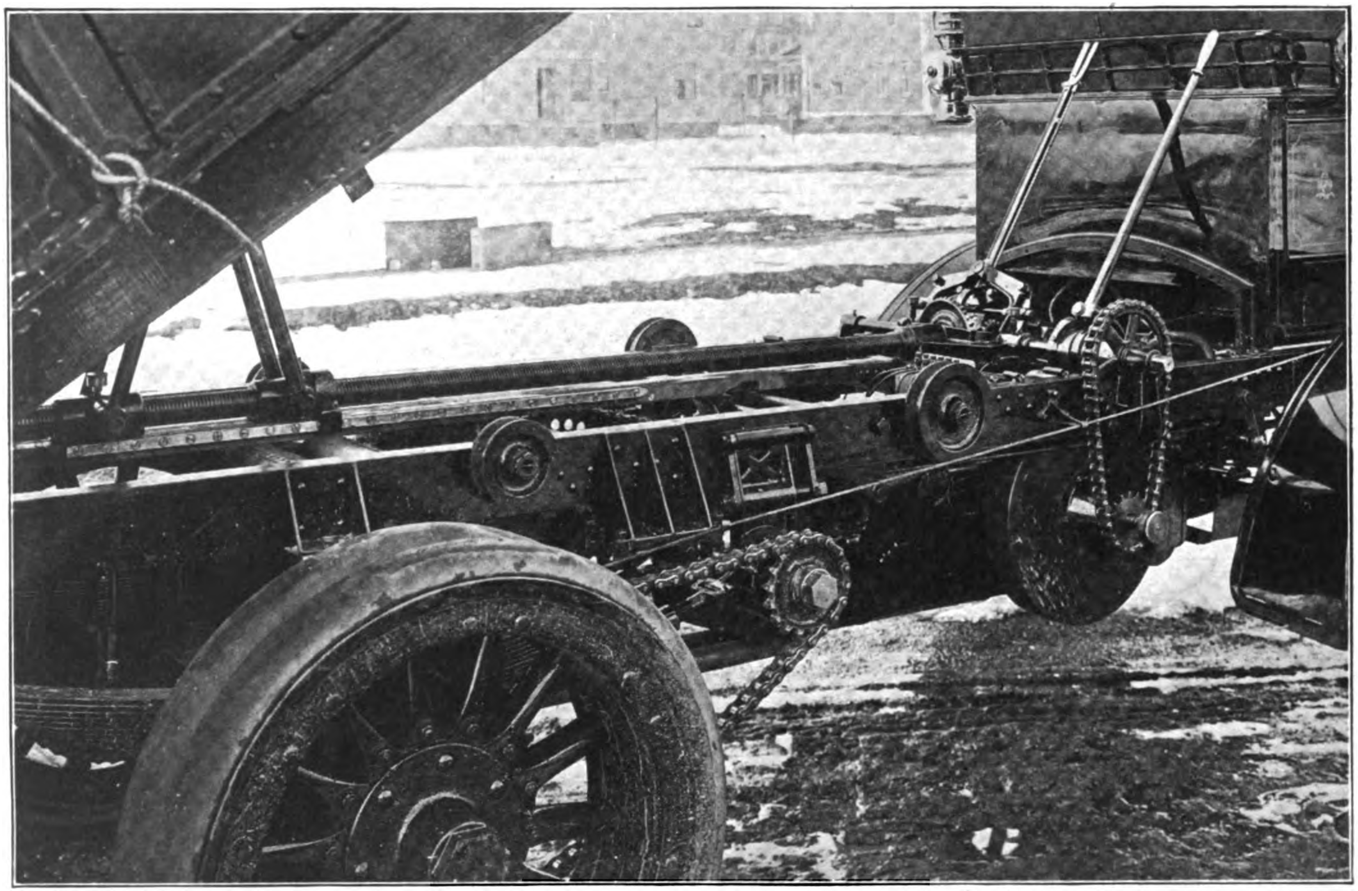


Fig. 94. Knox Contractor's Wagon Dumping a Load.

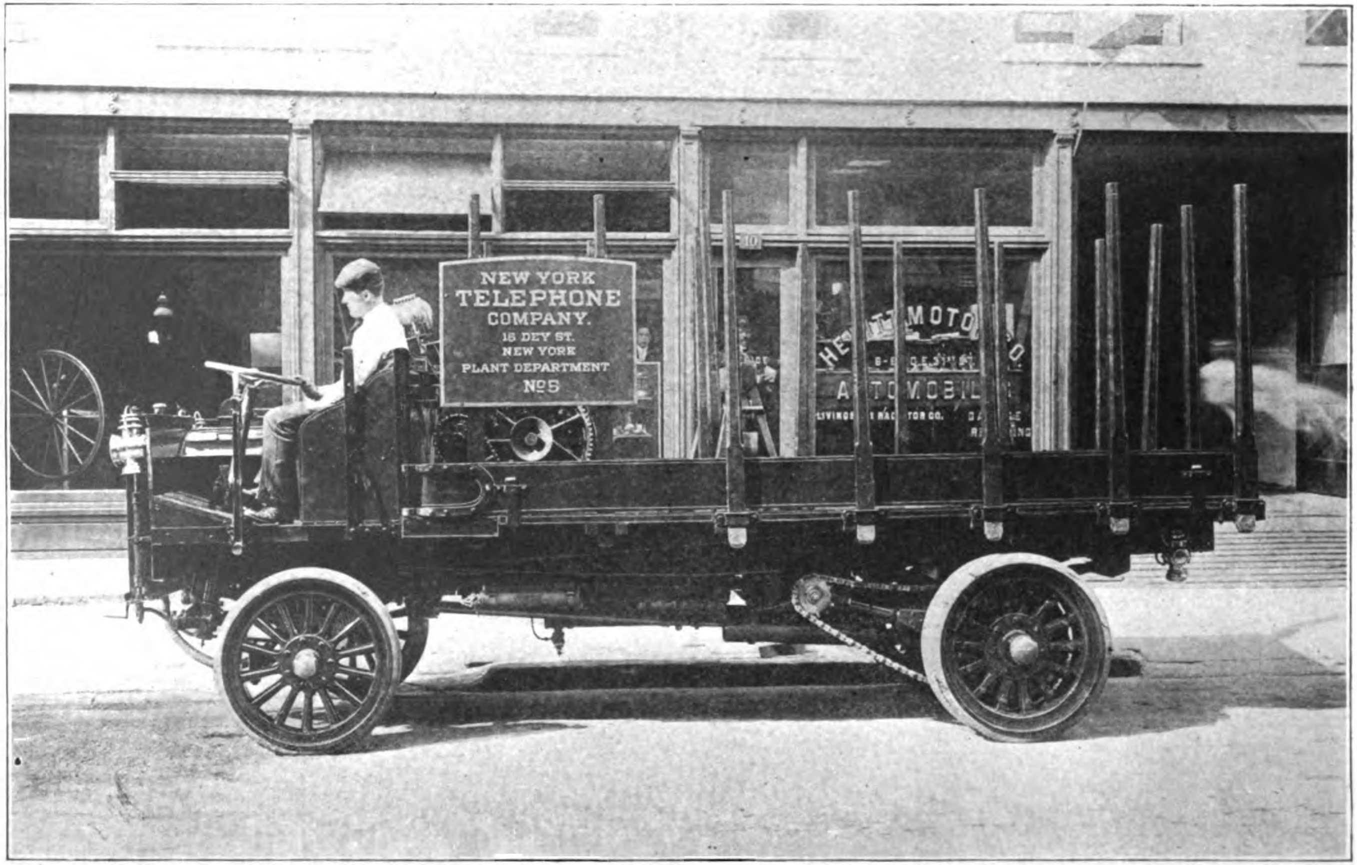


Fig. 95. Hewitt Truck Fitted for Telephone Cable Service.

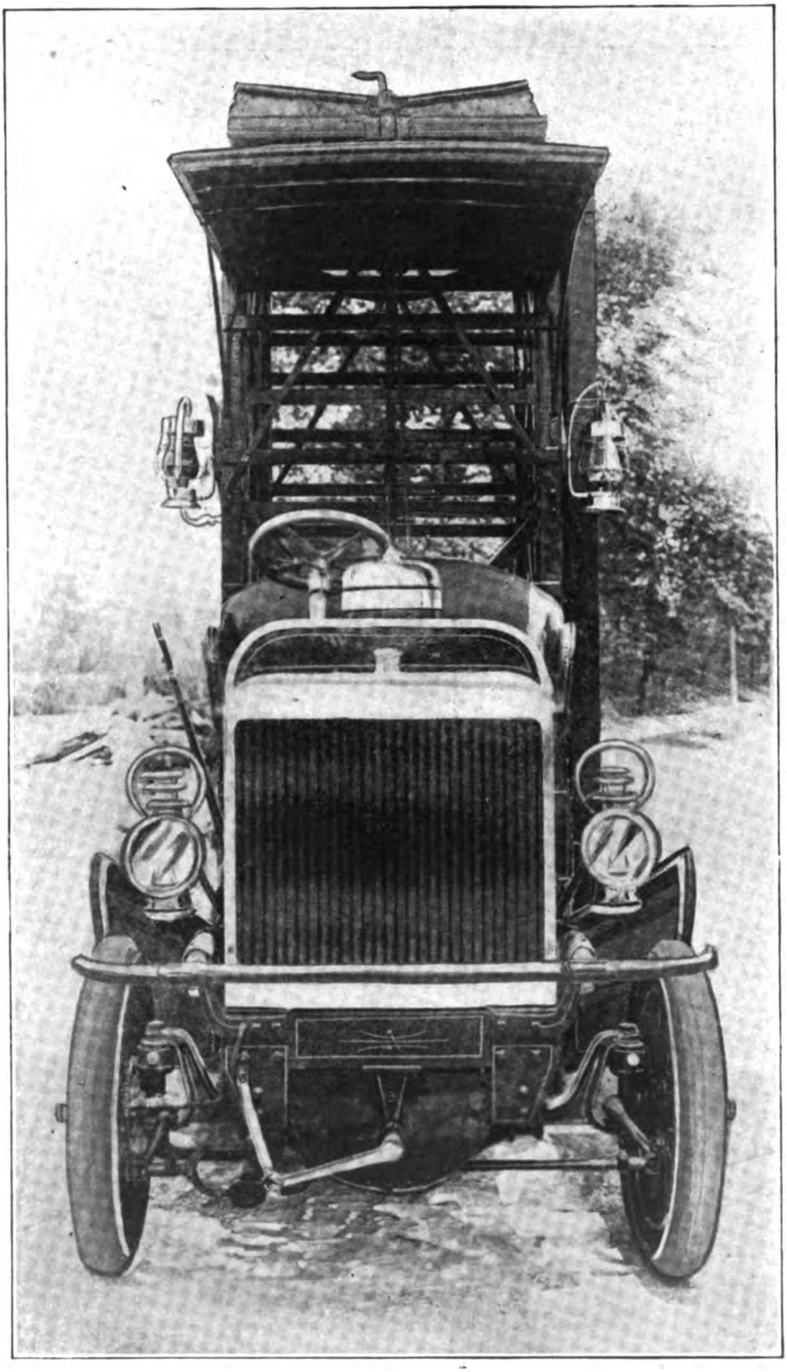


Fig. 96. Brennan Street-Railway Tower Wagon.

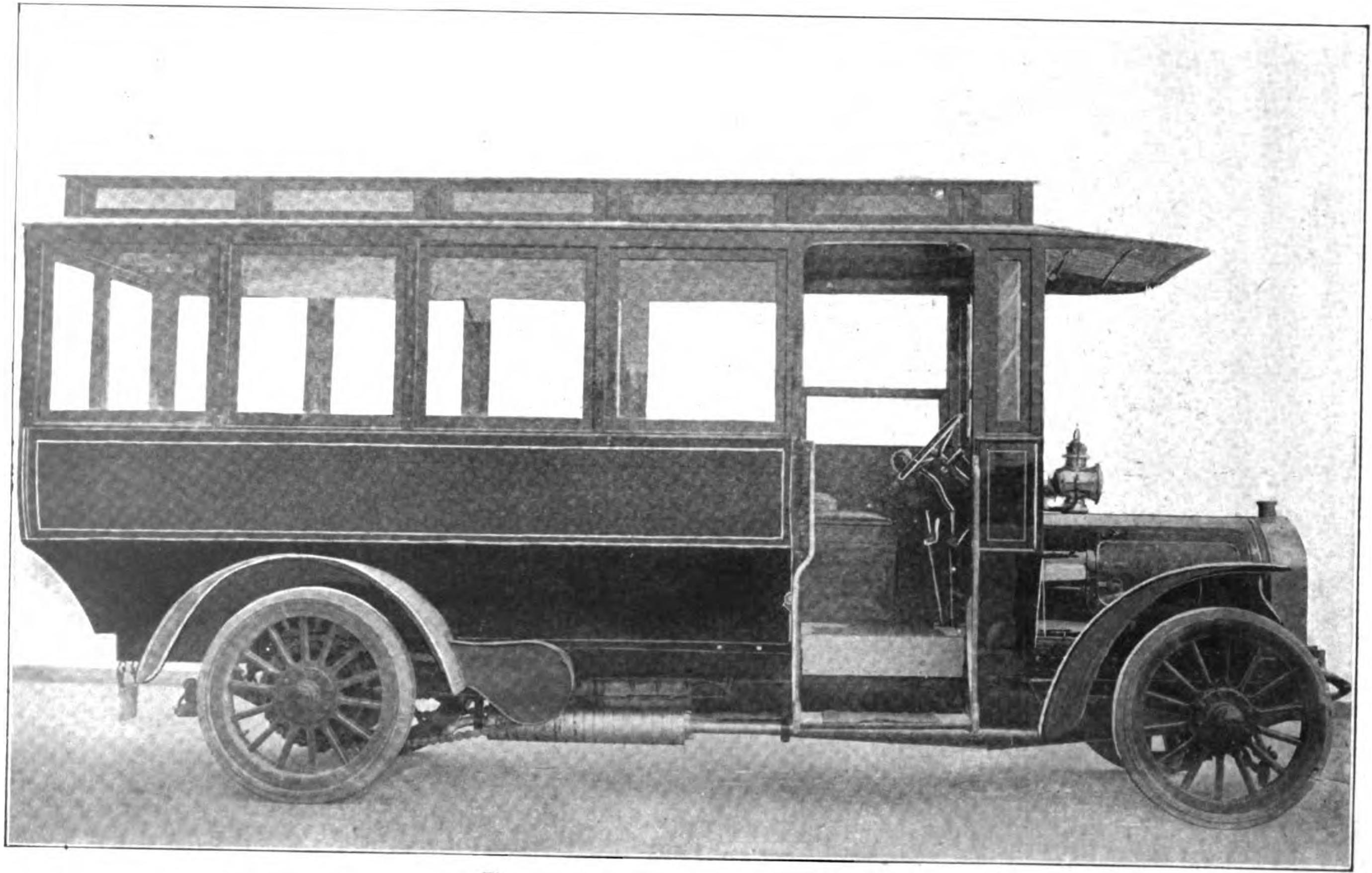


Fig. 97. Manhattan 16-Passenger Omnibus.

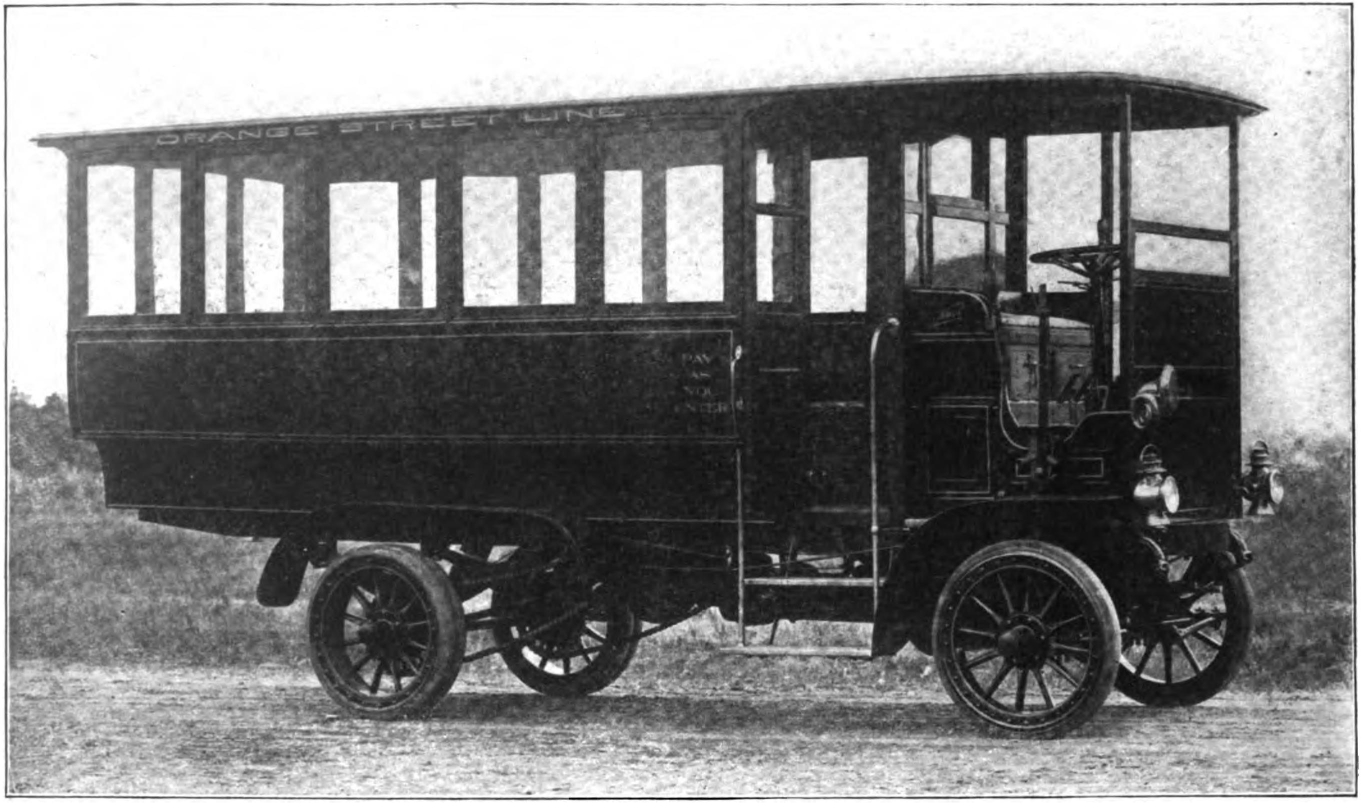


Fig. 98. Knox Omnibus.

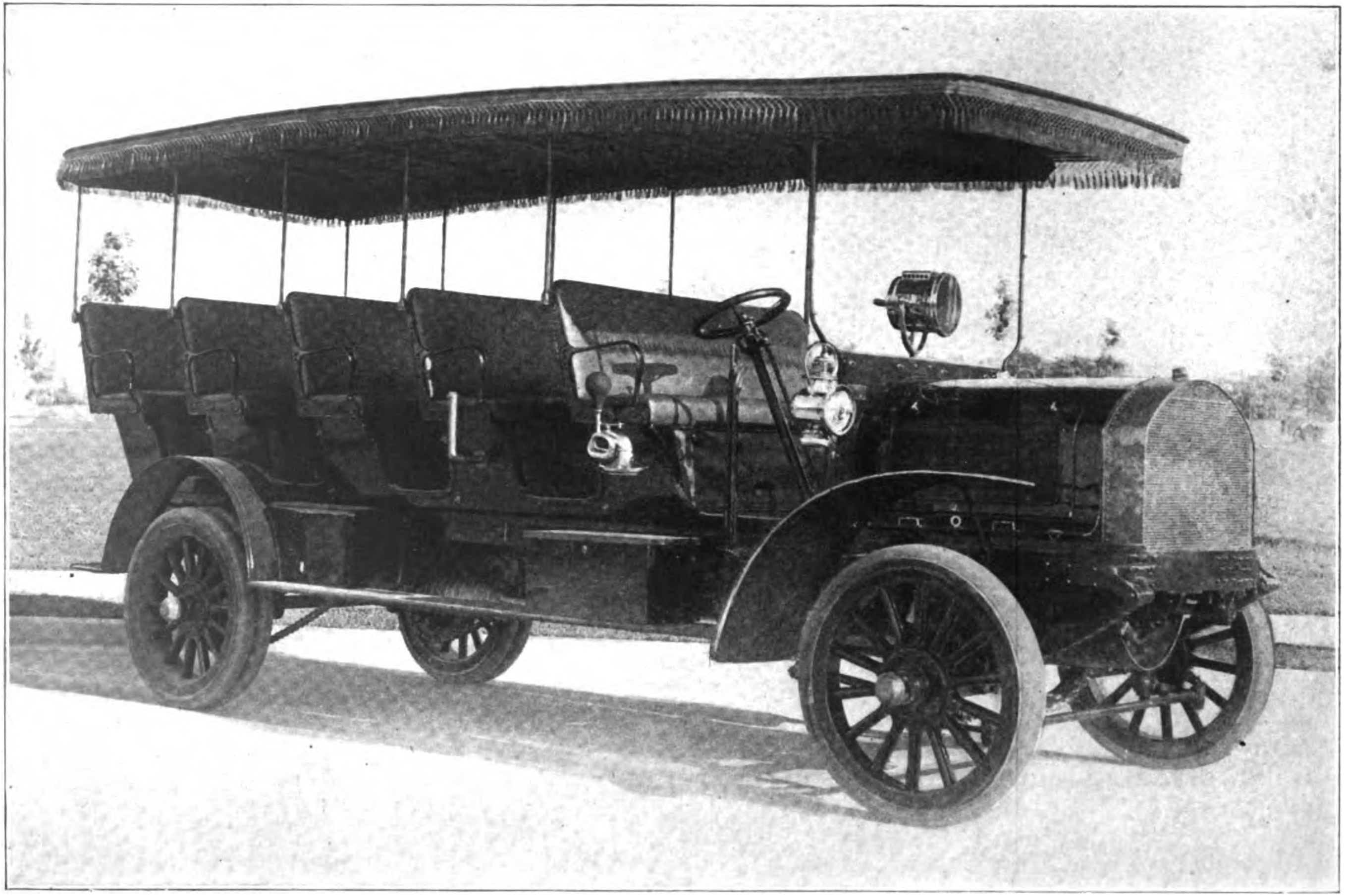


Fig. 99. Manhattan Sight-Seeing Wagon.

travelers linked to arms attached to the underside of the body engage the screw thread of the long shaft and slide on a narrow platform just beneath it. By throwing the left-hand operating lever in one direction the shaft is turned through one of the small bevel pinions so as to raise and dump the body. Engaging the opposite pinion reverses the movement and returns the body to its normal loading position, the entire operation only requiring a few minutes.

The Hewitt 3-ton truck, Fig. 95, affords another instance in which the power wagon presents a great advantage over the horse-drawn type for special service, this truck being equipped with a windlass driven by the motor and employed to haul the heavy, lead-encased telephone cables in and out of the conduits. In Fig. 96, is shown a Brennan 50-horse-power, emergency tower wagon used in the St. Louis street railway service. Speed is naturally its chief advantage as this permits it to effectively serve a territory of far greater area than would be possible with the use of a single, horse-drawn tower wagon. Fig. 97 represents a "pay-as-you-enter" type of bus built on a Manhattan 50-horse-power chassis and designed to be operated entirely by one man. It will seat 16 passengers comfortably. A lighter type of vehicle is shown in Fig. 98, this having as its foundation a Knox 40-horse-power, 4,000-powered chassis. A typical "sight-seeing" car is shown in Fig. 99, which is built on the same type of Manhattan 50-horse-power chassis as the bus, Fig. 97.

GASOLINE-ELECTRIC VEHICLES

Problems of Transmission. *Planetary Gearset.* Where the total weight to be transported as a unit is much in excess of five tons—which means five tons of useful load and anywhere from three to three and a half tons of dead weight in the shape of the vehicle—the use of a mechanical method of altering the ratio between the engine and the driving wheels presents far more than the usual difficulty. In large measure, this is due to the terrific stresses imposed on the gear teeth when starting the load from rest, and in order to provide for this adequately, the gear box as a whole must be made disproportionately large. It will be noted that the Hewitt 10-ton trucks employ a gearset, but this is of the planetary type in which the load is distributed over a number of comparatively small pinions which are always in mesh, thus obviating not only the high pressure per gear tooth, but likewise the necessity of sliding the gears in and out of mesh. This type of gearset has the further advantage of employing simple band clutches for the low and reverse speeds, which, like the remainder of its mechanism, are practically proof against abuse, even in the hands of the most unskilled driver. But it has the great disadvantage of not providing more than two speeds forward as a three-speed planetary gear involves an almost prohibitive amount of complication in design, because of the number of small pinions necessary. Its efficiency is, likewise, not as high as the sliding gear type, so that its simplicity and "fool-proofness" are its chief recommendations. With the exception of the Hewitt heavy trucks, it is not employed on anything bigger than a delivery wagon, or light truck, of about 1½-ton capacity.

Low First Speed. The fact that this planetary type of gearset is not capable of providing more than two speeds forward, means that the first speed has to be low enough to move the vehicle under any conditions that it is designed to meet. On a 10-ton truck, the first speed would not move the vehicle much in excess of two miles per hour, and as conditions under which the vehicle would be forced to drive on first speed would often occur, the motor efficiency would fall off in consequence. One of the chief and inherent short-comings of the internal combustion motor, as already pointed out, is its low torque, or pulling power, at speeds much below or above its normal r. p. m. rate. To work efficiently, it must accordingly be run as close to its normal speed as possible at all times.

Electric Transmission. It thus becomes evident that it is an important matter to provide as many speeds as possible or changes of gear ratio, between the motor and the driving wheels, in order that the motor may always be run at a practically uniform speed. For this reason, the sliding type of gearset with three or four changes of gear ratio is an improvement over a gearset providing but two forward steps; but even the former falls far short of providing the wide range of running speeds desirable for driving a heavy vehicle.

Up to the present, nothing but an electrical type of transmission has been found to afford the universal flexibility so necessary for starting and running a heavy vehicle and its load by means of an internal combustion motor. The initial expenditure involved in the building of a vehicle thus equipped is naturally far greater than where a purely mechanical form of transmission is employed, but it offers a number of advantages, not the least of which is its silence in operation as compared with a car with a sliding gearset.

Types. The electric transmission is a very desirable feature for passenger service on city streets and a number of buses of this type, Fig. 100, are in use on the Fifth Avenue stage line, New York. The equipment employed in its essential features is very similar to the tractor of the Sampson gas-electric road train described, Page 142. The usual four-cylinder, vertical, four-cycle gasoline motor is employed as the prime mover, direct coupled to a direct-current multipolar generator. This generator set runs at a uniform speed regardless of the load, or whether the vehicle is moving or standing still, although the motor may be controlled by the driver in exactly the same manner as when the transmission is mechanical. It accordingly uses fuel only in proportion to the demands made upon it, and as the motor speed is practically uniform at all times, the efficiency is high and the fuel consumption correspondingly lower than where the motor itself must provide for a large proportion of the speed changing. Where extra power is needed for an emergency the speed of the generator may be increased by running the motor faster, thus giving the set considerable overload capacity.

From the generator, the current is led through a control somewhat similar to that usually employed on street railway cars, so that in starting and stopping the vehicle, the driver does not have to shift gears or pay any attention to the motor, but depends entirely on the electric controller. The current is utilized to drive two direct-current, series-type motors, similar in design to those ordinarily employed on electric automobiles, but as neither the power nor the voltage is limited by the use of a battery, the current is employed at a higher potential, permitting the use of a very light and compact motor for the power developed. As will be plain from the illustration, these motors drive by gears to independent countershafts bolted directly to the motor casing. The countershaft carries a sprocket at its outer end from which a chain is taken to a larger sprocket on the driving wheel, giving a second reduction between the motor and the road wheels. As each motor drives its wheel independently, a differential is eliminated, and in case of accident to one of the motors the vehicle can be driven back to the station with the other.

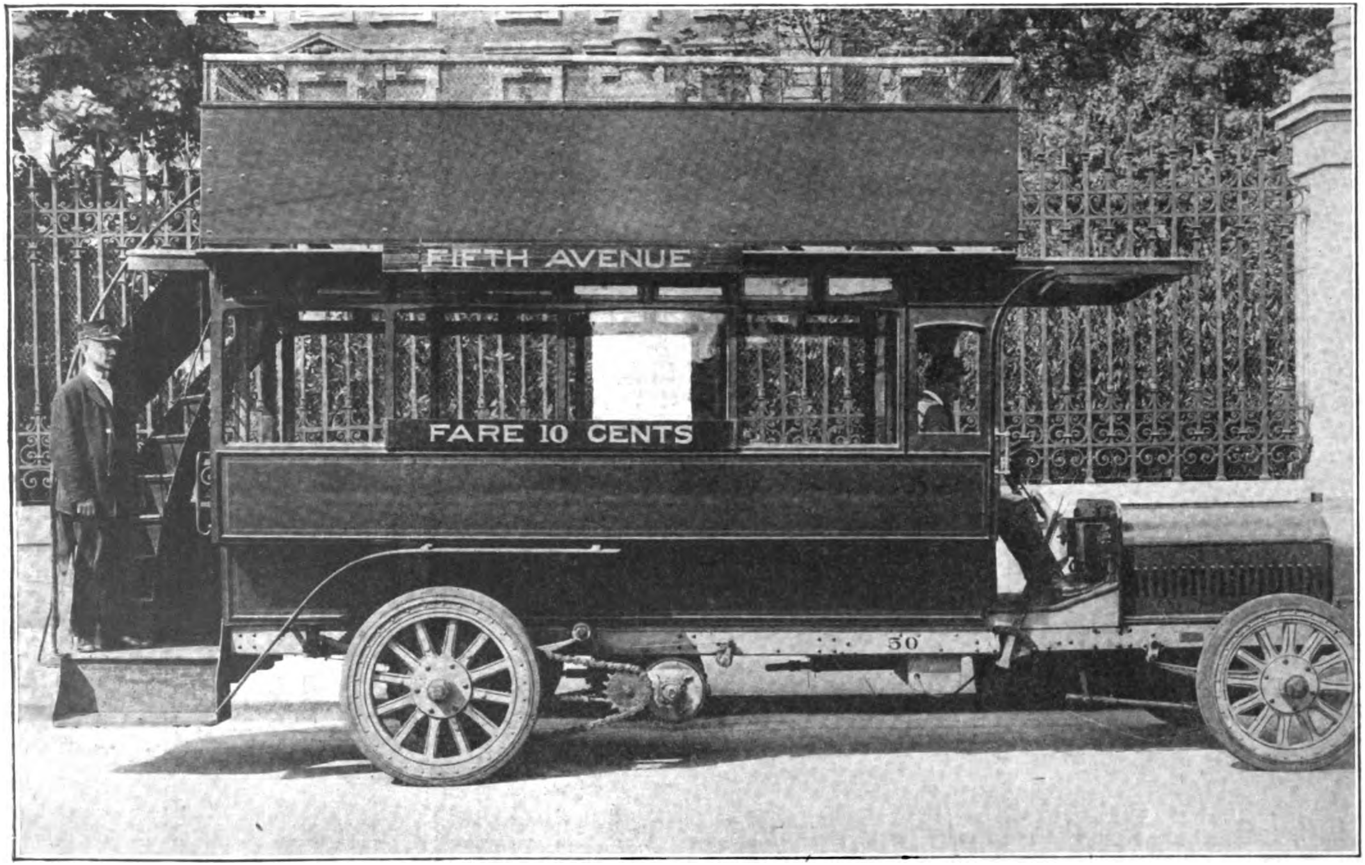


Fig. 100. General Electric Company Gas-Electric Bus.

The chassis of another form of gasoline-electric commercial vehicle is shown in Fig. 101. In so far as the power plant is concerned, this consists of the usual four-cylinder, vertical, high-speed, four-cycle gasoline motor, direct-connected to a multipolar, direct-current generator, the entire unit being mounted directly over the front axle and under the footboards as shown in the illustration. The controller of the street-railway type will be seen at the other side of the steering wheel, where its operating handle is most conveniently placed for the driver. The volt-ammeter will also be noted, mounted on the sloping part of the footboards and in plain view of the driver from his seat, while the rheostat will be seen attached to the chassis frame just forward of the rear wheels. The vehicle is known as the *couple-gear* truck owing to the fact that all four wheels are utilized for steering. The method of connecting the steering gear employed for this purpose is plainly visible in the view of a complete truck, Fig. 102. The drive takes the form of an independent electric motor incorporated directly in each wheel, all four being used for driving as well as steering, as described, Page 36. As every one of the wheels is employed to drive the vehicle, all are equipped with dual solid rubber tires, it being the usual practice to employ the latter only on the rear wheels of the ordinary form of truck.

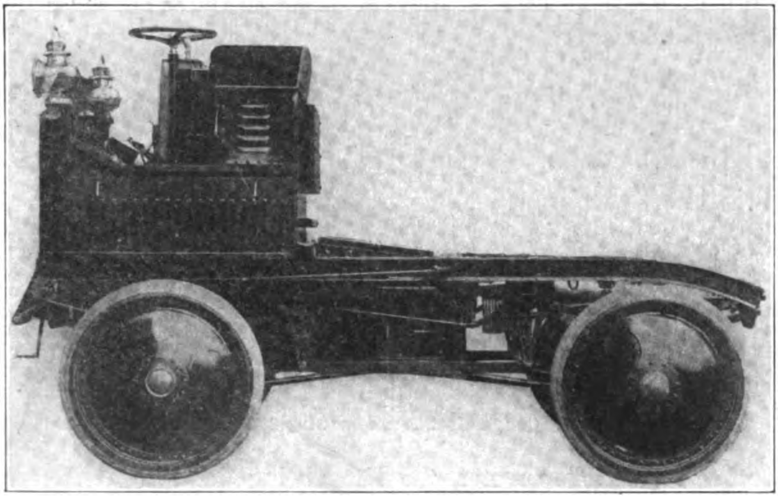


Fig. 101. Chassis of a Gasoline-Electric Truck.

As already pointed out, the gasoline-electric vehicles, or the gasoline truck with electric transmission, afford many advantages in the way of simplicity, combined with a practically universal range of speed changes, from starting to maximum, owing to the various relations that may be brought about between the generator and the motors with the aid of the controller. As a matter of fact, several speeds forward and two or three reverse are provided, which is naturally a far greater number than would be possible with any mechanical form of speed change. A further element of economy is contained in the fact that the speed of travel of the vehicle has no bearing on that of the gasoline motor, the latter being operated at its most efficient r. p. m. rate.

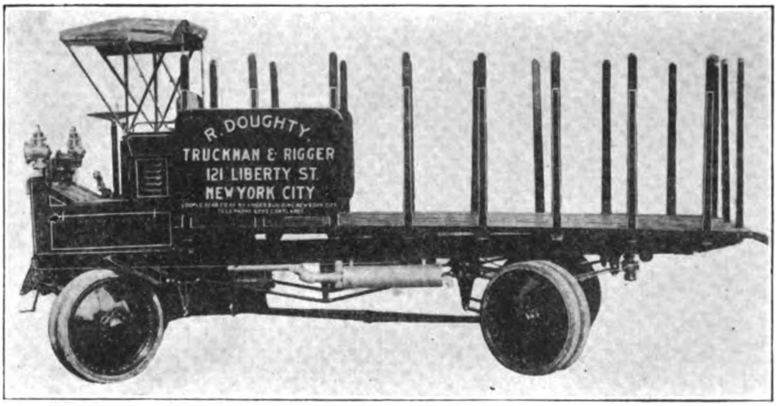


Fig. 102. Couple-Gear Truck Showing Steering Device.

These advantages have been found to offset the increased initial cost of building commercial vehicles of the gasoline-electric type, to judge from the number now in service. These vehicles have the further advantage of a low maintenance cost due to the great degree of simplicity and reliability which is characteristic of the electrical portion of the equipment. From the foregoing, it would appear as if the gasoline-electric type of vehicle was destined to fill a place of rapidly increasing importance in the field of commercial vehicles. The use of gasoline-electric street cars, treated in another article, shows the versatility of this method of propulsion.

STEAM VEHICLES

It will scarcely be necessary to mention the fact that the commercial steam vehicle has not been developed to any great extent in this country and is far from being a factor of importance in this field, as this is self-evident from the types of trucks in use. It might be inferred from this that steam had not been found particularly available for commercial use, but quite the contrary is the case, as in England it has doubtless reached about as high a degree of development as this form of power is capable on a road vehicle, while about as much attention has been devoted to it in France as here. As a matter of fact, the steam commercial vehicle has been developed in Great Britain at the expense of the gasoline type up to within a very few years ago. These steam cars, which are employed both in the form of "lorries" (trucks) and tractors, are ponderous and slow-moving affairs which, in some instances, are really not very far removed from the road roller and in others are about the same as the familiar farm tractor used here. But with all the inconvenience of burning coal and maintaining a boiler, they are clung to with a tenacity that is characteristic of British conservatism. They have the saving grace of being cheap and as they have served for some time past, they will doubtless hold on for some time to come.

Types. Specialized types of steam trucks have also been developed, in which the power-plant is in a very compact and efficient form, though none of the disadvantages of coal burning or very slow rate of travel have been eliminated. Two trucks of this type were tried out by one of the large express companies in this country several years ago, but it was evident from the first that they were not destined to fulfill American ideas of what the commercial motor vehicle should be, and a comparatively few months of service sufficed to demonstrate this.

Michigan. At the present writing there is practically only one specially-designed, steam commercial vehicle of American make on the market—at least, so far as the writer knows—excluding traction engines, of course. This is the Michigan steam truck, which is built in sizes ranging from 1-ton to 10-ton capacity, thus including delivery wagons as well as trucks from the smallest to the largest types now built in other powers. They are equipped with a quadruple compound-condensing engine, *i. e.*, there are two sets of four cylinders each, placed at 90 degrees to one another, the connecting rods of the opposite cylinders acting on a common crank pin. This engine is rated at 20 horse-power at 900 r. p. m., with an overload capacity of 100 per cent; it is non-centering and has no flywheel. Each group, or nest of cylinders, consists of high-, intermediate-, and low-pressure cylinders, all controlled by piston ring valves. All four pistons of each nest operate through two rods on one crosshead, and the crosshead operates through a single connecting rod on the crank on the shaft, the latter being provided with a balance weight. As already mentioned, the valves are of the hollow piston type, the valve-operating gear consisting of a spiral eccentric gear revolving on the shaft. This control permits of instant and easy reversing of the engine and is claimed to be very simple. The cylinders of the engine are of 2-, 2¾-, 3½-, and 5½-inch bore respectively, with a uniform piston travel of 3½ inches and a valve travel of ⅝-inch. The steam is cut off at ⅞-inch of the stroke, making the engine very economical. Its compactness may be judged from the fact it measures but 34 by 22 by 15 inches over all. It is connected with a 28-inch by 40-inch oiler. Steam is carried at 350 pounds to the square inch and is superheated. The general appearance of the engine is

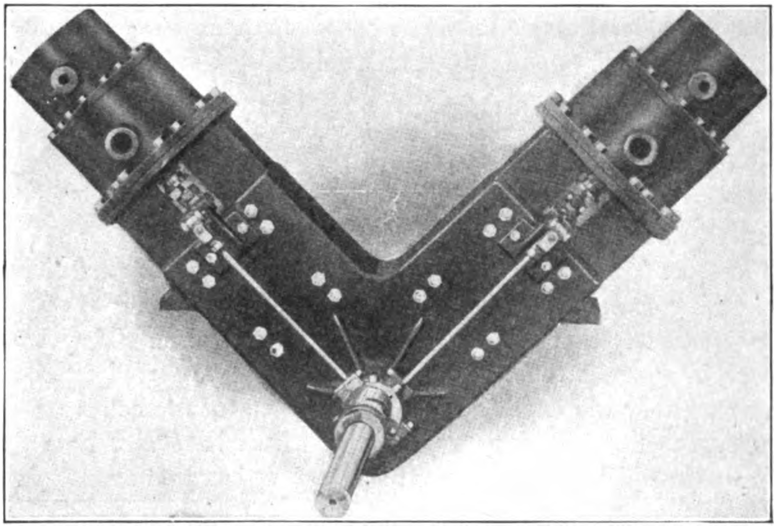


Fig. 103. Michigan Steam Motor Showing Valve Mechanism.

illustrated in Fig. 103. The high and first intermediate cylinders are controlled by one valve, and the second intermediate and the low by a second valve, the cylinders and valves being placed tandem. The valve mechanism on the back of the engine, as shown, runs direct from a reversing eccentric, operating on the shaft as a sleeve and with a spiral cut in it.

Generally speaking, the remaining features of the construction of the Michigan truck do not differ materially from those of the ordinary gasoline type. The motor is placed forward under a short bonnet, the condenser being placed in the usual position of the radiator, while the steam generator is under the driver's seat. Drive is direct from the motor through a long, horizontal propeller shaft to a bevel differential on a countershaft from which the power is transmitted by sprockets and chains to the rear wneels. The usual wheel steering is employed, the throttle being mounted on the steering pillar, while the hand levers shown are for reversing the engine and putting on the brakes. A 3-ton chassis is shown in Fig. 104.

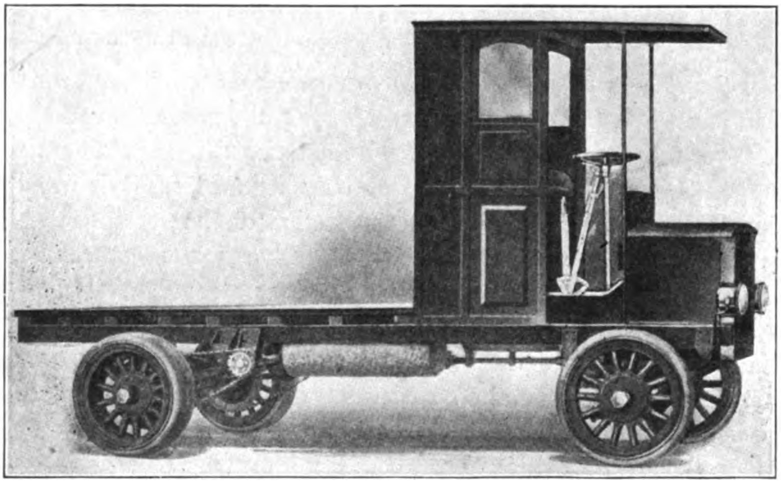


Fig. 104. Michigan Steam, 3-Ton Truck Chassis.

White. Apart from this specially designed steam truck, the only steam commercial vehicles on the American market are the White cars. Here the same chassis as is employed for the pleasure car is also used for commercial purposes and quite a number of vehicles have been supplied for ambulance, patrol, and other municipal service, as well as for the use of the Federal government. As is evident from Fig. 105, they do not differ in appearance from the usual gasoline type. The power plant of the White steam car consists essentially of a steam generator, a burner, and an engine, together with the necessary devices for supplying water to the generator and fuel to the burner, in proper amounts. The White steam generator does not resemble in any respect the ordinary steam boiler, and it has doubtless been due to its many points of superiority over the usual type of boiler for automobile service that these cars have met with such wide-spread success.

The White generator, in the first place, has the water at the top and the steam at the bottom, while the relative quantities of the two that happen to be present is of no moment, the generator containing but very little of either at a given time. In fact, the steam is generated instantaneously, and only as fast as it is needed, due to the continuous tubular construction of the generator, which is practically one coil, having but twelve joints, as compared with the many hundred in the usual fire- or water-tube boiler. The White generator consists of nine coils of steel tubing of ½-inch internal diameter, one above the other and connected in series, so that if straightened out, the entire construction would represent but a single piece of tubing. The water or steam, in order to pass from an upper coil to the one next below, must be forced up to a level above the top coil and then down again, preventing the water from descending by gravity and making the circulation dependent entirely upon the pumps. In operation, water is pumped into the upper coil and steam issues from the lowest coil. The precise point in its travel at which the water "flashes" into steam has never been precisely determined. From its action, this type of boiler is known as a *flash generator*, the small quantity of water and steam it contains at any moment being evident from the fact that its volumetric capacity is less than ⅓ of a cubic foot. But the process of making steam is so rapid that it is always available in the quantity the running conditions of the car may call for, this being governed by an automatic thermostat.

Beneath the generator is located the burner, to which the fuel, consisting of either gasoline or kerosene, is fed under moderate pressure, maintained by an air pump attached to and driven from the

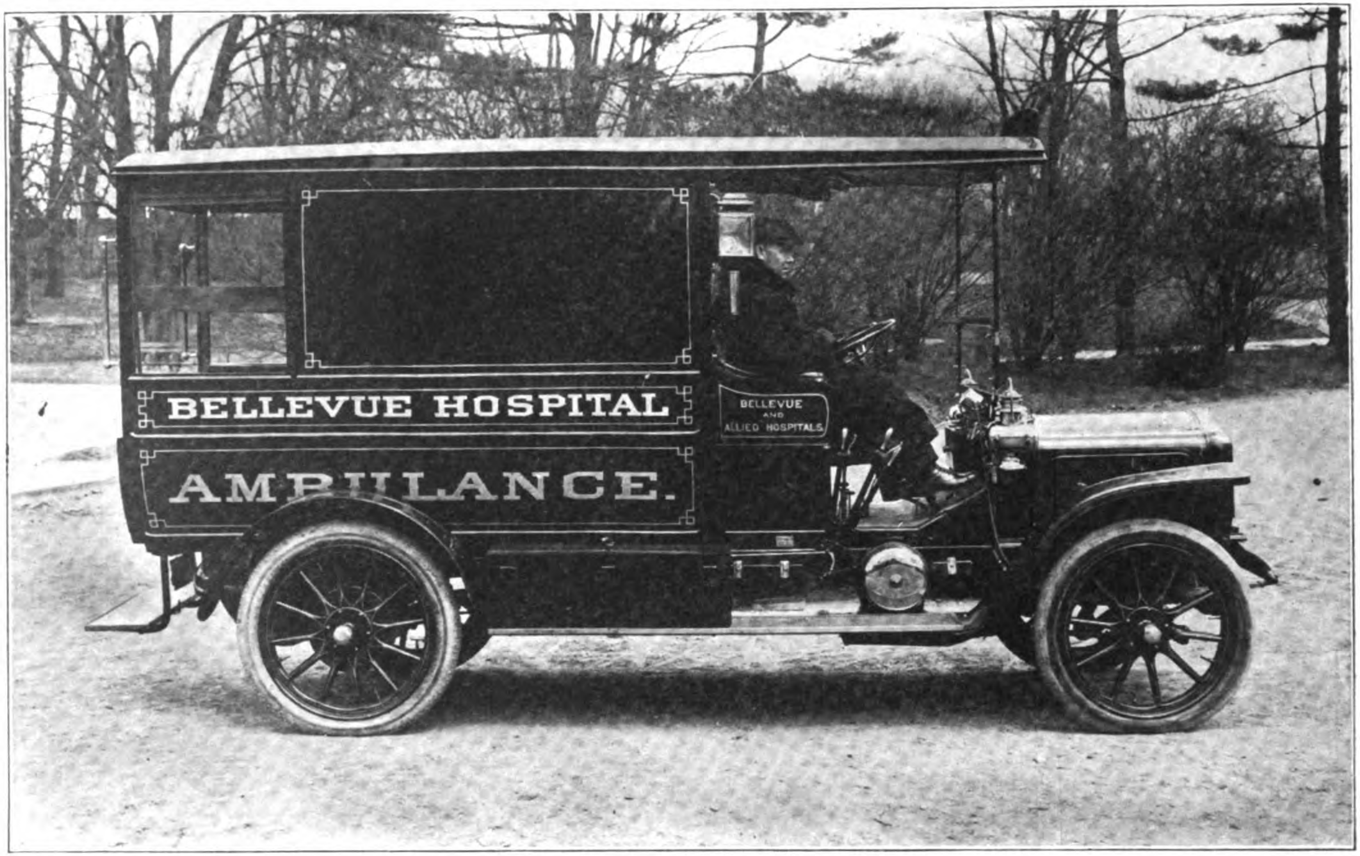


Fig. 105. White Steam Ambulance.

engine. The fuel first passes through a vaporizer and then, in the form of gas, enters the burner, where it mixes freely with air and

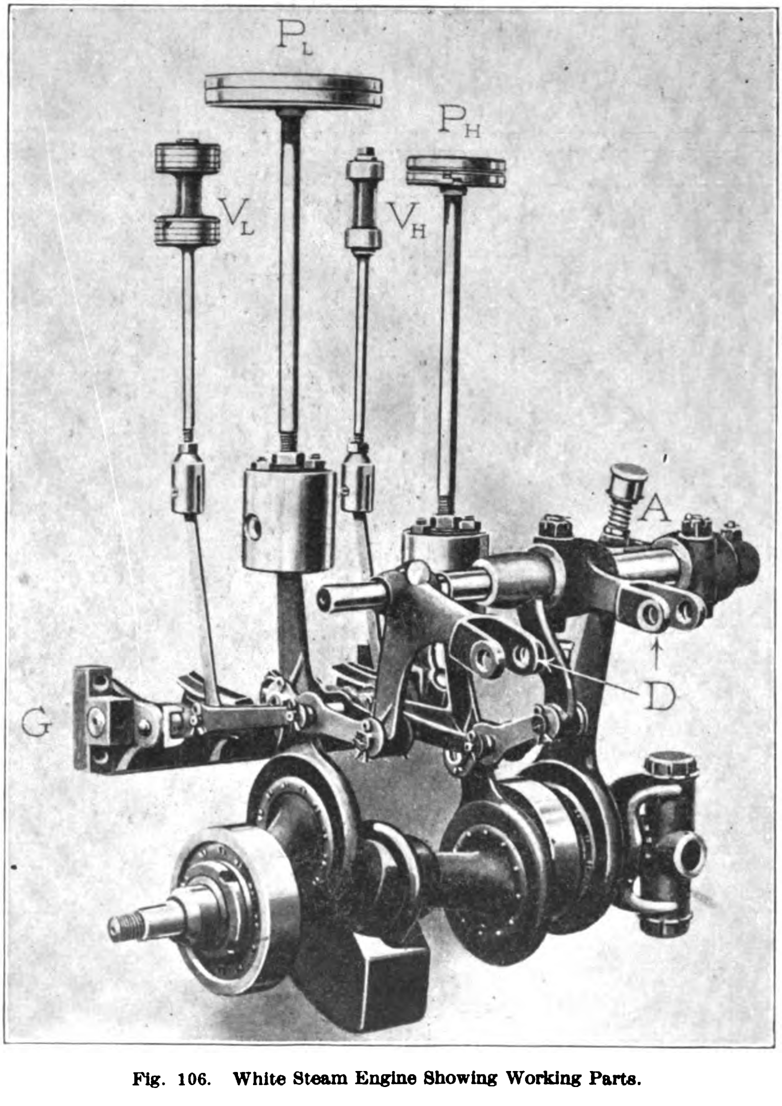


Fig. 106. White Steam Engine Showing Working Parts.

burns with a blue flame, as in the Bunsen burner. The products of combustion pass upward through the coiled tubing of the generator and are then conducted downward through an annular flue surrounding the generator and are led to the rear of the car where their escape is not noticeable. To start the burner, a pilot light is employed, the small flame of which is kept burning constantly while the car is in use. It serves the double purpose of keeping the vaporizer at the required temperature, and of lighting the burner whenever fuel is supplied to the latter. When kerosene is employed as fuel, it is necessary to use gasoline for the pilot light, but the quantity required is negligible. The vaporizer is a steel forging with a number of passages bored through it, and by its heat converts the fuel from a liquid to a gas.

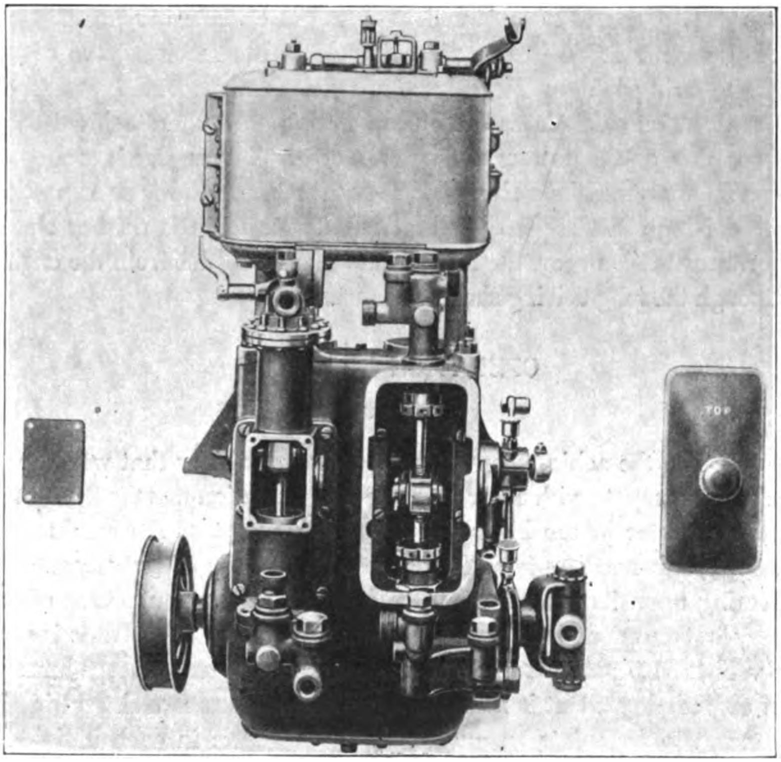


Fig. 107. White Steam Engine—Left Side—with Pump Covers Removed.

The engine is a two-cylinder, vertical, compound, condensing type designed to work at about 600 pounds pressure to the square inch. Its working parts, consisting of the crank shaft supported on large annular ball-bearings, pistons, connecting rods, crossheads, valve mechanism, and pump levers, are shown complete in Fig. 106. The valves are driven directly from the connecting rods by what is known as the *Joy type* of valve gear, the valves themselves being of the piston type. Steam is admitted through the center of the valve and exhausts at its ends; as the pressure is the same on all sides, a negligible amount of power is required to operate the valve. The crank case is made in one piece, access to the moving parts of the engine being had by large handholes, normally covered with light plates. The side plates are shown in Fig. 107, there being a third large plate on the bottom of the crank case. The engine is supported on two cross members riveted to the main frame and is so hung that the driving shaft is perfectly horizontal. As there is neither clutch nor transmission gear, the drive is direct and positive from the engine through the long driving shaft to the rear axle.

OPERATION PROBLEMS

COST

While the achievement of a degree of reliability that would permit it to compete with other forms of transportation was the first determining factor in the history of the development of the commercial vehicle, it is needless to add that the influence of greatest importance bearing upon its general adoption is cost of operation. One of the very first questions put by the intending purchaser is—"What is such a vehicle going to cost to maintain in service?"—and a large amount of engineering talent is now employed in the commercial field in the attempt to formulate an answer to this question in each individual case in which it is asked. In fact, the analysis of merchandise transportation requirements and the cost of the service as compared with old methods is rapidly developing into an engineering study of no mean proportions.

It will be evident that under the circumstances, definite figures are wanted by the purchaser, and they naturally can only be based on actual experience. The merchant who contemplates making a substantial investment in commercial vehicles wants to see something more than a mere calculation of what their services will cost—not for a month or two months, but, as closely as can be judged, the amount they will cost to run and maintain in repair during the first year and each succeeding year of the useful life of the vehicle.

There are naturally many factors to be taken into consideration in any complete cost-accounting system that is worthy of the name, whether this be for a single delivery wagon, or truck, or a whole delivery system, such as is employed by the large retail drygoods establishments. Lack of consideration of these numerous factors has led many commercial vehicle manufacturers into stating half-truths regarding the economic performances of their vehicles in the earlier days, though it is not certain by any means that the practice has entirely disappeared even now. The revelation of the whole truth naturally proved a disappointment to the pioneer motor-vehicle users, however, and the result was a feeling of distrust. It could not have been worse had the manufacturer actually made misstatements, for the user regarded them as such in the light of his experience. To cite instances of what is meant by these half-truthful statements, there may be mentioned the cases of cost summaries which some makers print in their catalogues. Sometimes these extend over a period of three months and in others, six months, and the service records thus established are expected to be regarded as a criterion of what the vehicle is capable of year in and year out. In some cases, nothing for tire replacement is included, owing to the short time the vehicle has been in use, not to mention such other items as depreciation, interest, insurance, and other overhead charges. Seldom, indeed, is the useful ton mileage of the car over the period in question given, and quite a number of manufacturers, when approached for information on this vitally important subject, are not loth to confess that they are unable to give it and that they have never attempted to keep a record of the kind.

Some of the factors of importance are speed, reliability, wide radius of travel, and even stylishness—which is considered an asset of the motor delivery wagon—but, after all, cost must be practically the sole governing factor by which the commercial motor vehicle is to be judged. At the outset, it was really the uncertainty—that lack of reliability which made the successful completion of a day's trip an entirely unknown factor—that first militated against the commercial vehicle; but since improvement in design, materials, and construction has eliminated that, the item of cost of operation is really paramount. It manifestly lies more within the province of an article on cost accounting for commercial vehicle service, than of one which deals almost entirely with the engineering side of the subject. Consequently, the aim has been more to demonstrate what the commercial vehicle is capable of—particularly as compared with former methods by horse haulage, figures on the cost of operation being cited more to show the superiority of the power wagon from an economic standpoint as well—rather than to attempt to set forth exactly what has been or can be done in operating one or more vehicles.

Gasoline. Leaving aside the matters of interest, depreciation, insurance, and repairs, it will be apparent that in the commercial vehicle, fuel, lubricant, and tires are of far more importance than in a pleasure car. One of the small 500-pound delivery wagons will usually travel from 25 miles to 30 miles on a gallon of gasoline, averaging better than 20 miles; a 10-ton truck will average less than three miles to the gallon of fuel. Between these two extremes, there is a wide range, a 1,500-pound delivery wagon running from 12 miles to 20 miles to the gallon, with an average of about 15 miles, while a 3,000-pound machine (the figures refer to load capacity and not to chassis weight) will not do better than from 8 miles to 15 miles per gallon, with an average around 10 miles. A 3-ton truck will range from 4 miles to 10 miles, the difference in every case naturally depending not only upon whether the vehicle is loaded or not, but also upon differences in the road surface and grades of its routes. The 5-ton wagon can travel from 3 miles to 5 miles on a gallon of fuel, its average being about 4½ miles as compared with 6 miles for the 3-ton size. A 14-ton road train may require as much as two gallons of fuel for every mile covered, but will doubtless not be found to greatly exceed a gallon to the mile, except where the going is particularly bad.

Lubricating Oil. The consumption of lubricating oil ranges between even wider limits than that of fuel, as will be apparent from the fact that in a commercial vehicle trial in which a large number of representative foreign vehicles competed, the ratio between the most economical and the most wasteful was fully five to one. In other words, some cars consumed five times as much lubricating oil per mile as others in the same class. But then certain of the European cars have proved to be highly economical in the use of lubricant and it is doubtful if there would be as wide a range between the same number of American commercial cars, as few of them have approached the degree of economy achieved in this respect by the French designer. Experience has shown that the minimum consumption of oil, which should be of the very best quality for the purpose, is about one gallon for every 14 to 15 gallons of fuel used by the vehicle, while the maximum is, approximately, one gallon for every six gallons of gasoline. Where much hill-climbing is the rule more oil would necessarily be used, owing to the motor running for longer periods on the lower gears and under correspondingly heavier loads. These figures are based upon ordinarily competent management of the machine, and while an expert driver, thoroughly conversant with his machine, and supplemented by painstaking garage attendance, might do somewhat better, incompetence in either of these departments can swell these figures so tremendously that there is no means of estimating to what proportions they may attain.

Tires. Next to fuel and oil come tires, and in figuring on this subject an engineer who has had five years' experience in the commercial field in a consulting capacity, gives the following: For a 500-pound wagon, ¾-cent per mile minimum, 2½ cents maximum, average 1½ cents; 1,500-pound class, or regular delivery wagon type, 1, minimum, 3½, maximum, and 2½ cents average per mile; 3,000-pound class, 1½, 5, and 3½ cents per mile; 3-ton class, 2, 7, and 4¾ cents per mile; 5-ton class, 3, 10, and 6 cents per mile. Against these figures, may be placed those which the builders of the Manhattan cars give as the result of five years' experience in the running of a large number of their own vehicles. Manhattan 2-ton truck, 2 cents per mile, the figure in each case being the average; 3-ton truck, 2½ cents per mile; 4-ton truck, 3 cents per mile; and the 5-ton truck, 4 cents per mile, this last falling between the minimum and the average for this class in the foregoing figures. Unfortunately no data is available at the moment on tire costs on the electric vehicles, though it may be stated definitely that owing to the lower average speeds and the greater ease with which the load is started by the electric motor, this type of vehicle shows much greater economy in tires than the gasoline car, though exactly how much is a question that could only be answered by a direct comparison of the figures.

Total Cost of Operation. The cost of operating various sizes of trucks is given in a different light by the makers of the Hewitt cars. The figures are based on five years' constant operation, the vehicle averaging 300 days in service—a task which should not be difficult of accomplishment. On this basis, and figuring an average run of 50 miles per day, the tire figures for a Hewitt 2-ton truck are given as $1.34 per working day, or $.0268 per mile, which will be found to practically agree with the averages already cited. On the same basis, the tire cost of the 3-ton truck, averaging 45 miles per day, 300 days in the year, for five years, is $.037, or slightly more than 3½ cents per mile, as compared with the average of 4¾ cents given in the first instance. This and other similar discrepancies between the two may well be accounted for by the long period of operation upon which the Hewitt averages are based, this naturally being more conducive to a favorable showing. Under similar conditions and averaging 40 miles a day, tire costs for a 5-ton truck are $.0583 per mile—practically the same as the 6-cent average for the same type in the first table. The cost of tire mileage naturally reaches its maximum on the 10-ton size, the Hewitt figures for their vehicles of this class being $.111 per mile, or between 11 and 12 cents.

From a basis of a five-year period of operation, it will be of interest to compare daily total costs of operation in a few instances. The following figures are given by the makers of the Manhattan trucks and are based on an average run of 50 miles per day. For a Manhattan 2-ton truck, the total daily operating cost—exclusive of depreciation, insurance, and similar items as already mentioned—is $5.88; composed of $1.50 for gasoline, five miles to the gallon at 15 cents a gallon; cylinder oil, one gallon, 38 cents; repairs and renewals 50 cents; tire changes, 2 cents per mile, or $1; and the driver's wages, $2.50. Similarly figured, the 3-ton truck will run 50 miles a day for $6.78, the 4-ton, $7.50, and the 5-ton, $8.00. According to the makers of the Manhattan trucks, these figures are based upon several years' experience in the handling of a large number of machines, and to show how closely they agree with what other makers have found under similar circumstances, they may well be compared with those of the Hewitt machines in the same sizes.

Taking the Hewitt figures on a daily basis, that of the 2-ton truck, based on exactly the same items, is $5.72 as compared with

$5.88, though labor in the case of the Hewitt is included at $3 per day, gasoline (15 cents per gallon) at only 90 cents, and lubricating oil (30 cents per gallon) at only 15 cents, while tire charges are more, or $1.34. In fact, there is hardly an item in which there is not a noticeable discrepancy, yet the totals are so close together as to be almost identical. In the 3-ton size, the charges are $6.22 per day of 45 miles travel, compared with $6.78 per day of 50 miles travel for the Manhattan, so that the totals are really equally close in this case as well. For the 5-ton, the cost is $8.30 for the Hewitt's run of 40 miles as compared with $8.00 for the Manhattan on the basis of 50 miles per day. That figures such as the above may be misleading to an intending purchaser will be evident from the further detailed costs cited by the makers of the Hewitt cars. These include every possible factor of expense, including depreciation, interest on the investment at 5 per cent, labor, tires, yearly overhauling, current repairs, gasoline, oil, total cost of insurance, and cost of storage and garage attendance.

They go to show that instead of involving a daily total expense of but $5.72, this should be $9.60 in the case of the 2-ton truck; $10.38 instead of $6.22 for the 3-ton size; and $12.67, instead of $8.30 for the 5-ton truck.

Mention has been made under *Gasoline-Driven Trucks* of the fact that the 10-ton size is about the maximum which it has been found commercially practicable to build as a single unit, the motor road train being employed where it is desirable to transport larger loads than this at one time. The Hewitt 10-ton truck is the only representative of this class and some figures of its service performance will be of interest. They refer to the truck, Fig. 75, and are based on what it did during the last four months of 1909. The daily run varied from 34 miles to 37 miles, with an average of 35.4. During 13 days in October, one of these huge trucks delivered 1092.39 tons of coal, the round trip varying from 5.5 miles to 15 miles. The average tonnage per day was 84.03, or 8.3 loads per day, which were made on an average gasoline consumption of a little less than 12 gallons, or 2.97 miles per gallon. The maximum cost of operation per day was $16, including all charges, which gave an average cost of $.19 per ton of coal for delivery. The weight of the empty car is 13,000 pounds, while the average weight of the load was 20,250 pounds, giving a total of 33,250 pounds and making the average rolling load, full and empty, 23,125 pounds. This gives a ton-mileage of 34.43 per gallon of gasoline, which is an excellent showing.

While no serious attempt has been made to analyze the cost of operation of the commercial vehicle on a general scale, the figures cited are all given as the result of several years' experience on the part of those who are in a position to be cited as authorities in the matter, so that the totals may be taken as a criterion. In other words, the student who finds himself called upon to analyze the cost of a motor delivery system and put his finger on the item that is making havoc with calculations made in advance, may take it for granted that the facts are fully representative of what may be accomplished by well-built cars of the heavier types in the hands of *competent* men—a term which is not intended to include either a factory expert or a novice.

FUELS

Gasoline. So long as gasoline represents not alone the most efficient fuel for use in motors of the present type, but likewise the most convenient, it will doubtless continue to be generally employed for pleasure-car use, regardless of its increasing cost. This effectively answers the question as to why kerosene is not used for pleasure-car propulsion. It is quite true that kerosene is cheaper and its value as a fuel for the internal-combustion motor is slightly greater than that of gasoline, but to realize its greater value it requires a motor designed to give a heavier initial compression. Furthermore, it is not as convenient as gasoline, for preheating is required to start the motor from cold, because of the higher specific gravity of *kerosene, which makes it less volatile, causing it to leave unsightly grease stains on anything with which it comes in contact.

Similar conditions naturally do not obtain in the commercial field, where the demand is for the most efficient and economical fuel. In view of the enormous increase in the demand for gasoline, coupled with the fact that the crude petroleum supply shows a constantly decreasing proportion of the more volatile products—the new wells of the Southwest are said to yield an oil producing not more than five per cent of gasoline in the process of fractional distillation—it is evident that it is only a question of a comparatively few years when gasoline will have reached a point where its use for commercial service will not be economically practical. By improving the methods of utilizing the fuel in the internal-combustion motor it will become possible to use petroleum of lower and lower grades, the Diesel motor now running directly on crude petroleum with an efficiency far in advance of the most economical steam plants as well as of most other forms of internal-combustion engine. But to accomplish this an extremely high compression is necessary—500 pounds to the square inch—and the weight involved in a construction required to stand such a pressure naturally makes the use of this type of motor out of the question on a vehicle. Instead of being employed in a carbureter in the manner usually followed on the automobile, air alone is compressed to this high pressure and the fuel is then injected in the form of a spray directly into the combustion chamber, at or slightly before the beginning of the power stroke. The heat generated by the extremely high compression automatically ignites the charge. While it does not appear probable that the employment of pressures sufficiently high to accomplish this will become possible on the commercial vehicle in the near future, the method of injecting the fuel directly into the cylinder, instead of first carbureting air as is now done, will doubtless have an important bearing on the solution of the fuel problem.

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*Note—Gasoline ranges from .62 to .67 sp.g. or 95 to 80 degrees Baumé, while kerosene is approximately .80 to .82 sp.g. or 46 degrees Baumé.

Alcohol. Though volumes have been written during the past few years, on the subject of alcohol as the coming fuel, it is the prevailing impression that despite favorable legislation which has made the employment of tax-free denatured alcohol possible, production has not reached a point where its employment on a general scale is commercially practical and that few attempts have been made to use it in actual service. The fact that gasoline can still be produced at a price which makes it impossible for alcohol to compete with it, has tended to delay the distillation of the latter on a large scale for fuel purposes, besides retarding the manufacture of engines specially adapted to burn it. When employed in an engine designed to run on gasoline, alcohol is neither commercially nor practically efficient, owing to its greater cost and the greater consumption per horse-power, as well as the lower output of the same size motor, due to the lower compression. But that it can be made so under proper conditions of operation is shown by the Hewitt trucks, described on Page 115.

The manufacturers of these heavy trucks offer their 5-ton and 10-ton types, equipped with a motor designed to run on alcohol without any extra charge to the purchaser. In these motors, the same quantity of alcohol develops a greater percentage of power than gasoline does in a motor designed for the latter fuel. While the burning of an alcohol-and-air mixture is attended by the generation of temperatures almost as high as the gasoline-air mixture creates, nevertheless, because of a peculiar phenomenon which has not been satisfactorily explained, a greater proportion of the heat is absorbed and there is considerably less tendency on the part of the motor to overheat when running under a heavy load. In other words, less of the heat that cannot be taken advantage of in the generation of power has to be absorbed by the water jackets and dissipated by the radiator. This is thought to be due to the fact that alcohol is never anhydrous. It is readily miscible with water, which is a tremendous advantage from the point of view of fire risk, and always carries five to ten per cent of water in solution. Steam is instantaneously generated by the heat of the explosion from this water in the mixture, and as it is far cooler at the moment of generation than the walls of the combustion chamber, it tends to absorb the heat that would otherwise have to be taken care of by the water jackets.

The makers of the Hewitt trucks state that their vehicles when equipped with the special alcohol motor and run on that fuel, will show an increase in mileage of fully 20 per cent over that possible with the gasoline motor per gallon of fuel. At the present prevailing prices for denatured alcohol, the cost of running a truck with it is estimated to be approximately $1.25 more per day than with gasoline. Furthermore there is, at present, no stability to the alcohol market and prices for this commodity might unexpectedly rise to a prohibitive figure. This has naturally deterred purchasers from investing in trucks equipped with alcohol motors, as the latter cannot be run on gasoline owing to the higher initial compression employed, which would cause pre-ignition.

Two years ago, the Department of Agriculture undertook an exhaustive investigation of the subject, and as the result of experiments made here and abroad, came to the following conclusions:

Alcohol contains 0.6 of the heating value of gasoline, by weight, and in the department's experiments a small, single-cylinder engine —designed to run on gasoline—required 1.8 times as much alcohol as gasoline per horse-power hour. This corresponds very closely to the relative heating value of the fuels, indicating practically the same thermal efficiency with the two when vaporization is complete.

By proper manipulation, any engine on the American market today, designed to run on gasoline or kerosene, can be operated on alcohol without any structural change whatever. In some cases, however, carbureters designed for gasoline cannot properly vaporize all the alcohol supplied, and in such cases the excess of alcohol consumed over gasoline, is greater. But the absolute excess of alcohol consumed over gasoline will be reduced by such changes in the design of the engine as tend to increase its thermal efficiency.

By altering the design of the carbureter and increasing the initial compression materially, any engine built to run on gasoline will show an increased thermal efficiency and will then consume less alcohol per horse-power hour in proportion to this increase. An engine designed for gasoline or kerosene will, without any material alterations being necessary to adapt it to alcohol, show slightly more power (approximately 10 per cent) with alcohol than with the fuels for which it was designed, but this increase is at the expense of a greater consumption of fuel. By making alterations designed to adapt the engine to the new fuel, this excess can be increased to fully 20 per cent. Different designs of gasoline and kerosene engines are not equally well adapted for burning alcohol, though all will do so with a fair degree of success.

The storage of alcohol and its use in the motor is attended with much less danger than that of gasoline, and the exhaust from the alcohol motor is not as apt to be quite so offensive as that from a gasoline motor, though an excess of lubricant and imperfect combustion will create an odor when the engine is not properly handled. This is now an important factor in city traffic, as pointed out in connection with taxicab operation, and is daily becoming more so as the number of vehicles increases.

No more skill is required to operate an alcohol motor than one designed to run on gasoline, and the combustion chamber of the former does not show the same tendency to soot up, nor does it, with proper operation, show any effects of corrosion. By reason of greater cleanliness in handling the fuel, increased safety of storage, and less offensiveness in the exhaust, alcohol engines will sooner or later begin to displace the gasoline motor, particularly when the production of alcohol reaches a scale where its use will be on practically the same economic level. It has been thought that in this field, it would be impossible to conveniently increase the compression of the motor because of starting difficulties, but as the compression release employed for starting on many gasoline motors is equally applicable to the alcohol motor, this should not prove a deterrent.

In many localities, it is unlikely that alcohol power will be cheaper, or as cheap as gasoline power for some time to come, but in isolated districts such as those to which the motor road train is particularly adaptable, the possibility of distilling the alcohol fuel right on the ground would be a decided advantage, both practically and economically. The raw materials ordinarily employed for this purpose are sugar-mill waste (whether cane or beet), cornstalks, any vegetable refuse or similar materials of a very inexpensive nature, it having been demonstrated that it is possible to distill aclohol on a commercial scale from the pine sawdust of the southern lumber mills.

Producer Gas. So far, only the possibilities of employing a form of liquid fuel have been considered, owing to its high value for the purpose per unit of volume, as well as the ease with which it may be stored and carried on the vehicle. Lack of these advantages would appear to make the employment of any form of solid fuel out of the question on an automobile. In fact, coal or coke, as a substitute for alcohol, gasoline, or similar liquid fuels would hardly appear to promise much for the commercial vehicle, whether from the standpoint of economy or convenience. Experience with stationary plants of all sizes has conclusively demonstrated, however, that these two fuels when converted into a combustible gas and used in the internal-combustion engine, are far more economical than any liquid fuel, no matter how cheap, or than the same weight of fuel burned under a boiler and converted into power through the medium of the most advanced type of steam engine.

Hitherto, the size and weight of the necessary apparatus for converting the solid fuel into the gaseous state has rendered its adaptation to the automobile impractical. Four years ago, however, the problem appeared to have been very satisfactorily solved in Great Britain by the design of a gas-producer which was brought down to such a degree of compactness as to make the entire plant quite suitable for installation in a commercial vehicle of the medium and heavy types. The modifications necessary to adapt such a plant to the confined space, as well as the arrangements required to render its operation easy, will be plain from the description.

Of course, none of the essentials, such as the fuel hopper, air blower, water-feed pump, gas cooler, washer, and water tank have been omitted. The plant is as complete as any used in the largest stationary installations and the method of operation is the same. As employed in the service in question, the producer was installed on a double-decked omnibus equipped with a 40-horse-power, six-cylinder, vertical, four-cycle motor, identical in all respects with those employed with gasoline as fuel, except that the carbureter had been removed and the inlet manifold connected directly with the gas bag attached to the outlet of the producer. The latter is mounted directly in front of the dash of the car and is so compact in design as not to add greatly to its length. The producer consists of a comparatively light malleable-iron casting while the supply of fuel is carried in a sheet-metal tank, or hopper, fitted with large handholes, or openings for rapid refilling with coal or coke.

The producer is fitted with a special grate bottom, an ashpan, and cleaning cover, and above the grate on the side of the producer body, a breach is fitted with a large lid for the purpose of cleaning and lighting the fire. The top of the producer is open to the fuel hopper, the fuel feeding automatically from the latter by gravity as fast as it is consumed. An outlet for the gas in the form of a vertical tube passes up through the bottom, terminating near the top, while an open end is provided, surrounding which is a pendant tube of large diameter, fixed to the top of the inner side of the hopper, this tube being perforated at its lower end. To maintain the draught of air necessary, a small centrifugal blower is installed and arranged to be driven directly from the motor through a ratchet device similar to that used on the starting handle of a gasoline motor, thus permitting it to be rotated by hand when the motor is not running. A similar device is also used on this crank handle, so that when the motor is running, the handle is idle.

In this producer, air is conveyed from the blower to the under side of the grate through light copper tubing, which is used to cut down weight. A spring-controlled relief valve is employed on this tubing to keep the air pressure uniform, while the water supply is maintained by a small, single-acting, ram type of pump, which is also driven by the motor. The cooler is composed of gilled tubes placed vertically, to permit any dirt or grit to fall into a well or sump placed at the lowest part of the apparatus, and in which there is always a supply of water to catch it. As it is necessary to clean and purify producer gas before it can be used in a motor, a washer is always employed. This is formed of a tube fitted with a screen and a set of baffle plates and is maintained partly full of water at all times. The object of the latter is to relieve the gas of all fine dust and grit that it carries in suspension, and to accomplish this the gas is passed directly through the water. From the washer, it passes to a gas bag, which is fed by pressure from the producer, through the cooler and washer to the control valve, this valve being automatically operated by the flexible cover of the gas bag. As the engine draws in a charge, the bag naturally contracts, causing the cover to open the control valve and permitting the entrance of a fresh supply of gas from the producer. The throttle is operated in the usual manner, an auxiliary air valve being fitted to enable the driver to vary the strength of the mixture in accordance with the demands made upon the motor. It might appear from the description that such a plant would necessarily be cumbersome and weighty, but such is not the case. Longitudinally it occupies less than one-fourth the space required for the six-cylinder motor, while vertically, it extends at its lower end to about the level of the axles and at its upper end not quite as high as the dash; the fact that the weight of the complete producer and its auxiliaries does not exceed 250 pounds, effectually disposes of the weight question.

Exhaustive tests were carried out to demonstrate the practical working of the plant, as well as its cost of operation as compared with fuels such as gasoline and kerosene. Two producers were built, one small enough to feed the single-cylinder, 3½-horse-power motor of a small runabout, which serves to show in what a very limited compass the complete apparatus may be accommodated, while the other was fitted to a car having a four-cylinder, vertical, 30-horse-power motor. For actual service, a producer was mounted on the 40-horse-power, six-cylinder bus mentioned. Coke was used as a fuel and tests showed that to run the latter vehicle, 19½ pounds of fuel and two gallons of water were necessary per hour. Coke, of the grade used for this purpose, costs about .3 of a cent per pound placed on the car, making the cost of running a vehicle with an engine of this size approximately six cents per hour, as compared with gasoline at 15 cents a gallon and kerosene at 10 cents, the consumption of liquid fuel on the same car amounting to from two to four gallons per hour. It will be evident that this results in an unusually favorable showing for the producer.

The motor can be started within five to ten minutes from *all cold,* the operation merely consisting of getting the fire under way and supplying air for a few minutes by means of the hand-crank attachment to the blower. After this, the car runs the same as one using liquid fuel. The driver has little additional work to perform than where gasoline is employed, as the mixture is fed and controlled automatically by the gas bag and its valve. During the tests in question, speeds ranging from 3 miles to 40 miles an hour were attained, the supply of gas being steady and under perfect automatic control at all times.

While the foregoing will be of considerable interest as showing the possibilities of solid fuel on the commercial vehicle, it is naturally doubtful if any serious attempt will be made to develop it further while the possibility exists of obtaining ample supplies of liquid fuel of one sort or another at a cost so low as to give the commercial motor vehicle its present inestimable superiority over horse traction. One of the chief difficulties encountered at first in the use of producer gas in stationary plants was the amount of fine dust and grit carried into the cylinders by the gas, despite the washing process, and it is evident that this condition would be aggravated where space and weight limitations restrict the size and efficiency of the washer, the result being a scoring out of the cylinder walls and a loss of motor efficiency. On the whole, it seems quite probable that alcohol will prove the legitimate successor of gasoline once the point is reached when the cost of the former places it at an economic advantage.

TIRES

It may seem strange at first glance, that the matter of providing the commercial vehicle with suitable tires should have presented any problem for the designer to solve. Of all the materials that might appear to be suitable for the tires of a business wagon, rubber is the best adapted to the purpose for a number of reasons. This is frequently but erroneously termed "hard rubber" as the rubber, although usually solid, is not what is known as hard rubber, the latter being a substance that has been vulcanized until it has assumed the closeness of grain of very hard wood. Rubber is preferred for tires, because of its ability to absorb vibration and because of its excellent traction, the latter naturally being its chief advantage.

Steel. From this it will be apparent at once why steel tires have not been employed—first, because they would not provide sufficient traction, and second because the pounding, which they would impose on every part of the mechanism would be ruinous. Steel tires are employed on the Sampson road train, but it will be noted that the driving wheels are equipped with cleats to give sufficient traction and the speeds are low. In addition, the mechanisms of both the tractor and the trailers are of the simplest form, designed to stand the roughest kind of treatment. In view of the nature of the service for which a motor road train is intended, and the character of the country in which it is used, steel tires would doubtless form the only practical solution of the problem.

Wood. Next to steel, wood appears to have advantages in this field, which have not yet been fully realized. Its coefficient of friction with the ordinary road surface is far higher than that of steel and its traction is accordingly much better. It also acts as a deadener of vibration to some extent, though not as valuable for this purpose as rubber. On the score of economy, however, it is vastly superior to both steel and rubber.

So far as the writer is aware, the only instance in which wood tires are now employed, is to be found in the Avery tractor, which is really a 3-ton truck designed to meet practically all the requirements of farm use. In the wheels of the Avery, hard wood plugs are set on end around the periphery of the wheel, as may be noted by referring to the illustration of this vehicle, Page 133. The device seen outside the wood-tired wheels has been designed especially to enable the vehicle to travel over soft ground, as in hauling plows, and while it also comes into action when the car is acting as a tractor on the road, it is not, strictly speaking, a tire. Wood has also been experimented with in the shape of blocks set on end and fastened in the felly of the wheel, but the fact that such a tire has never come into use would seem to show that is was unable to meet the requirements. The wood plug tires employed on the Avery are said by the makers of that machine, to prove very effective in the service for which they have been designed.

Rubber. No difficulty was experienced in the employment of solid rubber tires on light and medium weight vehicles, and had the commercial car never outgrown the delivery wagon stage, there would doubtless never have been any tire problem. As commercial vehicles increased in capacity, however, the solid rubber tires grew in size to correspond, and trouble was immediately encountered in the use of anything larger than a six-inch tire in one piece on a driving wheel. An eight-inch, one-piece, solid, rubber tire was manufactured for use on the driving wheels of a heavy truck but proved an utter failure. This was due to the fact that solid rubber is practically incompressible —next to water, it is probably the least compressible substance known.

Bearing this in mind, the reasons for its failure as a large single tire will easily be appreciated. Take a 5-ton truck as an example. Loaded, the total weight on the tires would be at least 16,000 pounds, depending on the weight of the vehicle itself. As ordinarily designed, a heavy commercial vehicle carries about three-fifths of the entire weight on the rear wheels, say 10,000 pounds in this case, which probably is very close to the reality. Such a truck, equipped with an 8-inch, one-piece, solid-rubber tire would doubtless have in contact with the road surface at its driving wheels, an area of 8-inch by 2-inch or a total of about 16 square inches for each wheel. As each driving wheel is carrying a load of approximately 5,000 pounds, this means a pressure of nearly 310 pounds to the square inch at the point of contact.

While rubber is not compressible, it is elastic, which many erroneously regard as the same thing. Due to this elasticity, the rubber of the tire in contact with the ground, is forcibly squeezed out. In other words, it is simply displaced owing to the great pressure.

But as neither this, nor the remaining rubber in the tire can be compressed to an appreciable degree, it must go somewhere. Its only escape is from the rim of the wheel altogether and it either disrupts the tire or pulls it off the rim. No form of mechanical fastening that can be devised is sufficient to hold a large, one-piece rubber tire on its wheel, and the idea of employing it in this form has had to be abandoned. The action of rubber under great pressure will illustrate the difference between elasticity and compressibility. For example, the only difference between attempting to compress rubber and a solid rock would be that the former would yield by displacement, if free to do so, as in the case of a tire, which is only confined laterally, while the latter would remain inert until the pressure became sufficient to crush it.

This peculiarity of rubber was allowed for in two ways, first, by splitting the rear tire into two units above a certain size, thus permitting the wave of displaced rubber to bulge laterally to a greater extent than where it was in one piece; and, second, by sectioning the tire, or dividing it into blocks of rubber, instead of a continuous piece. By allowing just sufficient space between the blocks to compensate for the amount of rubber displaced by the pressure, these tires have proven very effective in service. A continuous tire of the Firestone dual or twin type is shown in cross-section in Fig. 108 and the following weights are given by the manufacturers as representing the extreme load per wheel that should be carried on solid rubber tires of this type:

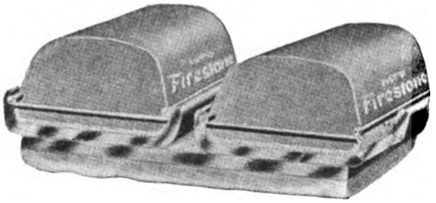


Fig. 108. Firestone Twin, Solid Tire.

For a 2-inch tire, 500 pounds per wheel; 2½-inch, 750 pounds; 3-inch, 950; 3½-inch, 1,375; 4-inch, 1,750; 5-inch, 2,000; 6-inch, 3,000; and 7-inch, 4,000 pounds weight per wheel. In the dual type two 2½-inch tires have a capacity of 1,900 pounds, exceeding by 400 pounds that of two single tires of the same size. Two 3-inch, will carry 2,500 pounds; two 3½, 3,500; and two four-inch—or a *dual four-inch* as it is known—will bear 5,000 pounds per wheel. Firestone tires of this kind are made with cross-bars of steel vulcanized right into the rubber near the base of the tire and made an actual part of it. The tire itself is immovably held in the channel by two endless retaining wires which press firmly upon the shoulders formed by the cross-bars. These dual tires have such an advantage over the single tire, that the latter is now only employed on the lightest vehicles.

The second and more successful solution of the problem where the very heavy vehicle is concerned, is shown in Fig. 109. This is the

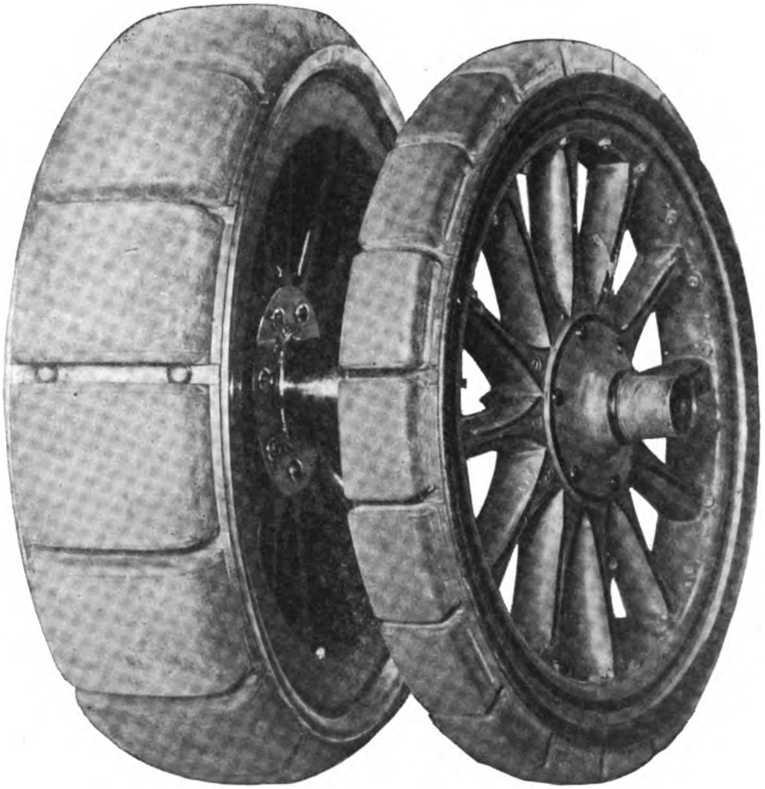


Fig. 109. Kelly-Springfield Block Tire.

Kelly-Springfield block tire and in the form illustrated shows tires appropriate for the front and rear wheels of 5-ton to 7-ton trucks. Each block of rubber is independently fastened by being slipped through an opening in a steel plate corresponding very closely to its size. These blocks have a spreading base of strongly reinforced material, so that when the steel rim is bolted in place they are very firmly held. Four sections of steel rim are employed to each complete wheel. The use of a tire composed of separate blocks not only eliminates the tendency to creep on the rim or jump off altogether—which marked the single-piece, large-sized tires—but it also reduces to a large extent, the internal or molecular action of the rubber, which causes heating and is detrimental to the life of the tire. The space between the blocks not only allows for the expansion or displacement of the rubber, but also gives greater traction, acting somewhat after the manner of a series of cleats, but without the disadvantages of the latter. The block construction also makes the tire much cheaper to maintain and repair, as where a section of a continuous solid tire is accidentally cut or badly damaged, it involves an expensive repair during which the tire must be out of service, while with the block construction; any one of the units may be replaced in a few minutes at comparatively small expense. The metal frame and the rubber blocks are illustrated in Fig. 110. A tire of this kind of the average diameter is composed of from thirty to forty blocks, and for carrying weights in excess of a certain load per wheel, are made in dual form on the drivers, the blocks, in this case, being placed in staggered relation, as shown by the illustration. Based upon wheels of not less than 36 inches in diameter, the extreme carrying capacities of tires of this type are given by the makers as follows: For 3½-inch tires, 1,200 pounds; 4-inch, 1,500 pounds; 5-inch, 2,000 pounds; 6-inch, 2,800 pounds; 7-inch, 3,500 pounds; and 8-inch, 4,500 pounds per wheel respectively. Typical equipment for 4-ton and 5-ton trucks would be 4-inch single front and 5-inch dual rear; for 6-ton and 7-ton trucks, 5-inch single front and 6-inch dual rear; while for 10-ton trucks, 5-inch single front and 7-inch dual rear. One of the wheels of a 10-ton Hewitt coal truck equipped with tires of this type is shown in Fig. 111.

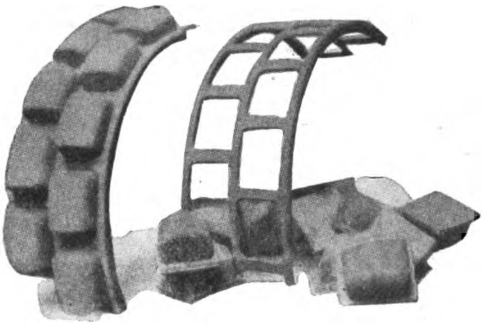
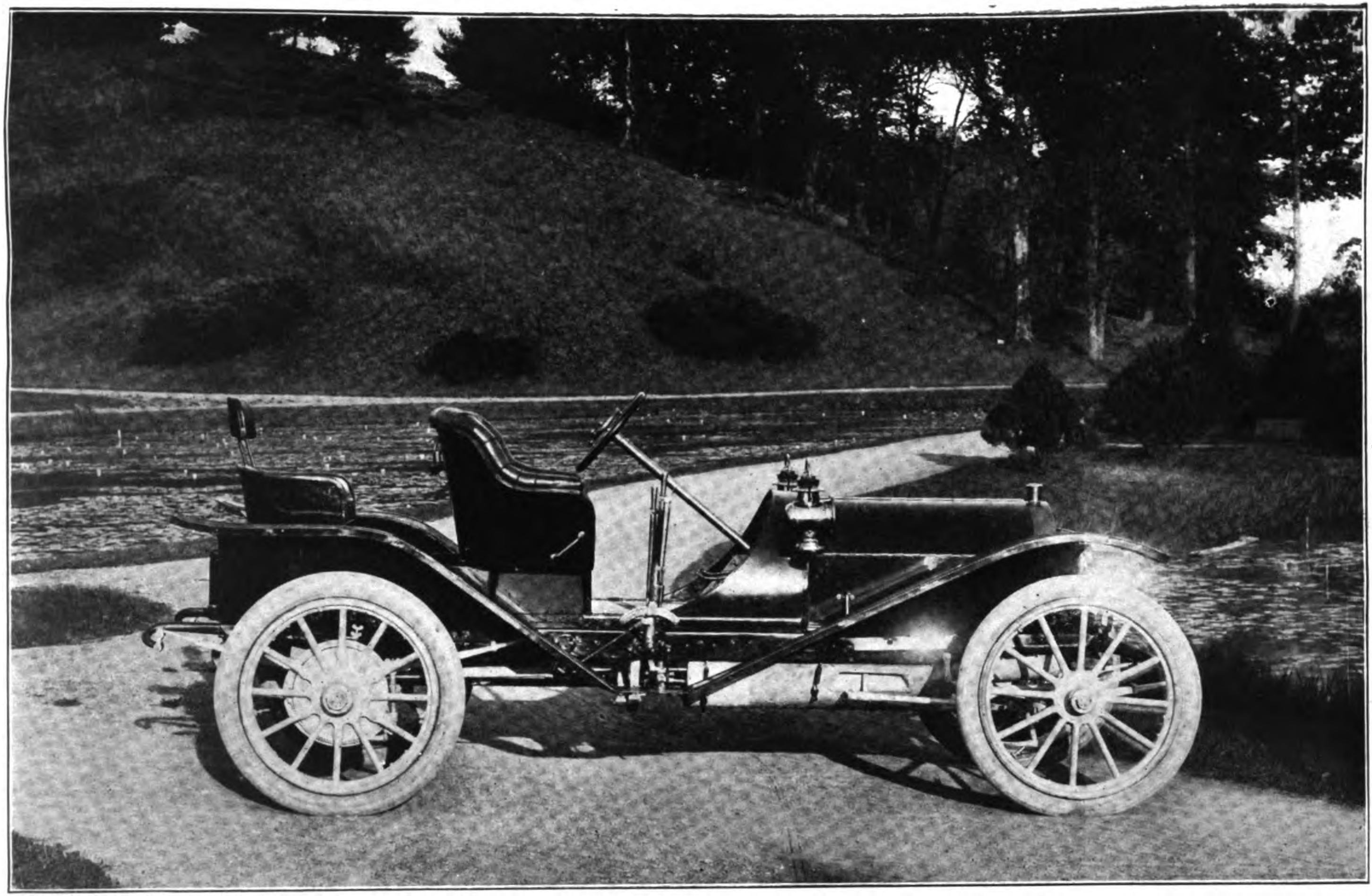


Fig. 110. Metal Tire Frame and Blocks.



TOURING RUNABOUT
Stevens-Duryea Company, Chicopee Falls, Mass.

MANAGEMENT

The discussion of the taxicab has revealed the fact that the success of a commercial vehicle in service depends to no little extent upon its operation. The designer has made every effort to reduce its mechanism and control to such absolute terms of simplicity that little or no discretion is left to the driver, but it is naturally out of the question to eliminate the personal equation entirely. The electric vehicle means the closest approach to this ideal and therefore has an advantage where the grade of labor to be employed is in question.

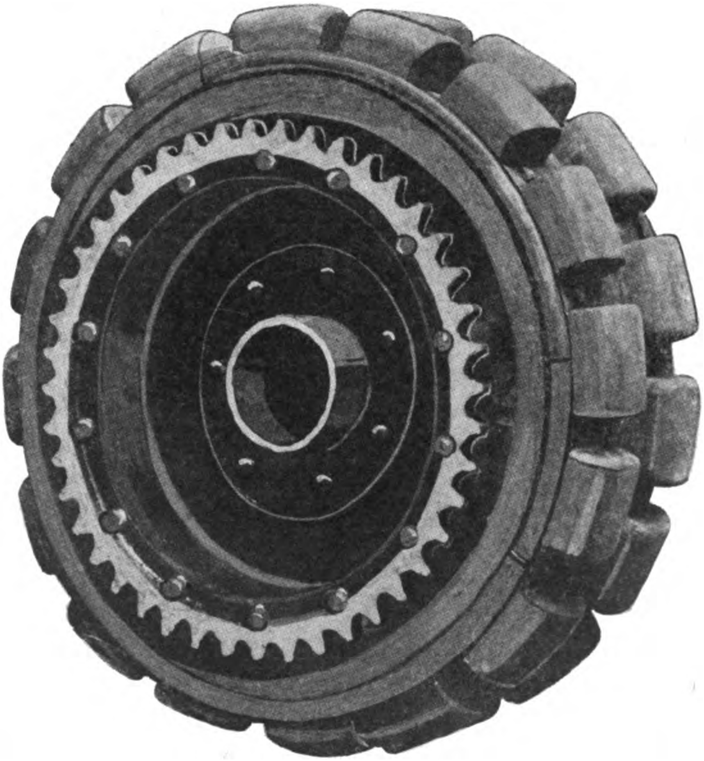


Fig 111. Wheel of Hewitt 10-Ton Truck with Kelly-Springfield Dual Block Tire.

Conditions where the gasoline-driven vehicle are concerned, are quite different, and to this fact has been due, in no small measure, much of the reluctance displayed by business men who were experienced in other forms of motoring, in adopting the power wagon for their commercial needs. The training of a sufficient number of men to properly handle gasoline trucks has presented a real problem, which has been rendered far more difficult by the lure of pleasure-car service at rates of compensation beyond the standards permissible in the commercial field. Thus, many drivers, once they had mastered the handling of a truck, immediately deserted this field for the much higher compensation of a chauffeur's position, and the process of training had to be repeated, often to the detriment of the vehicle itself. The labor problem is one, however, that will provide its own solution in the course of time.

The investment represented by the average commercial vehicle, whether a delivery wagon or a truck, is so much greater than that called for by a horse-drawn unit of the same type, or even its equivalent in horse-drawn equipment, that radically different methods of operation are called for if the overhead expense is to be kept down to a working minimum. In other words it does not pay to permit the motor vehicle to stand idle at all, if it can be avoided. That this is possible to a very large extent is manifested by an ingenious arrangement devised by the Wanamaker delivering service in New York. In common with other establishments of its kind, the Wanamaker store maintains a delivery service extending over a wide radius in and around New York. Near-by deliveries are made direct by the wagons which return to the store for reloading, while outlying districts are served by wagons which receive their loads from a distributing station conveniently located in that district. These distributing stations receive their supplies in large quantities from the store in motor trucks, such as the 3-ton Packard truck, Fig. 112, several of these being employed for the purpose. But as a body of the size shown would take some time to reload or empty of comparatively small packages, false bodies, or crates, have been designed to fit snugly inside the real body of the truck. These false bodies are taken right into the shipping room and packed, ready to be lifted into the elevator and rolled directly into the waiting truck, its return to the store and its departure with a new load thus being a matter of only a few minutes, so that one truck can serve several distributing stations at outlying points.

Where but one or two vehicles are to be maintained, as in the case of the small establishment, it will doubtless be found not alone

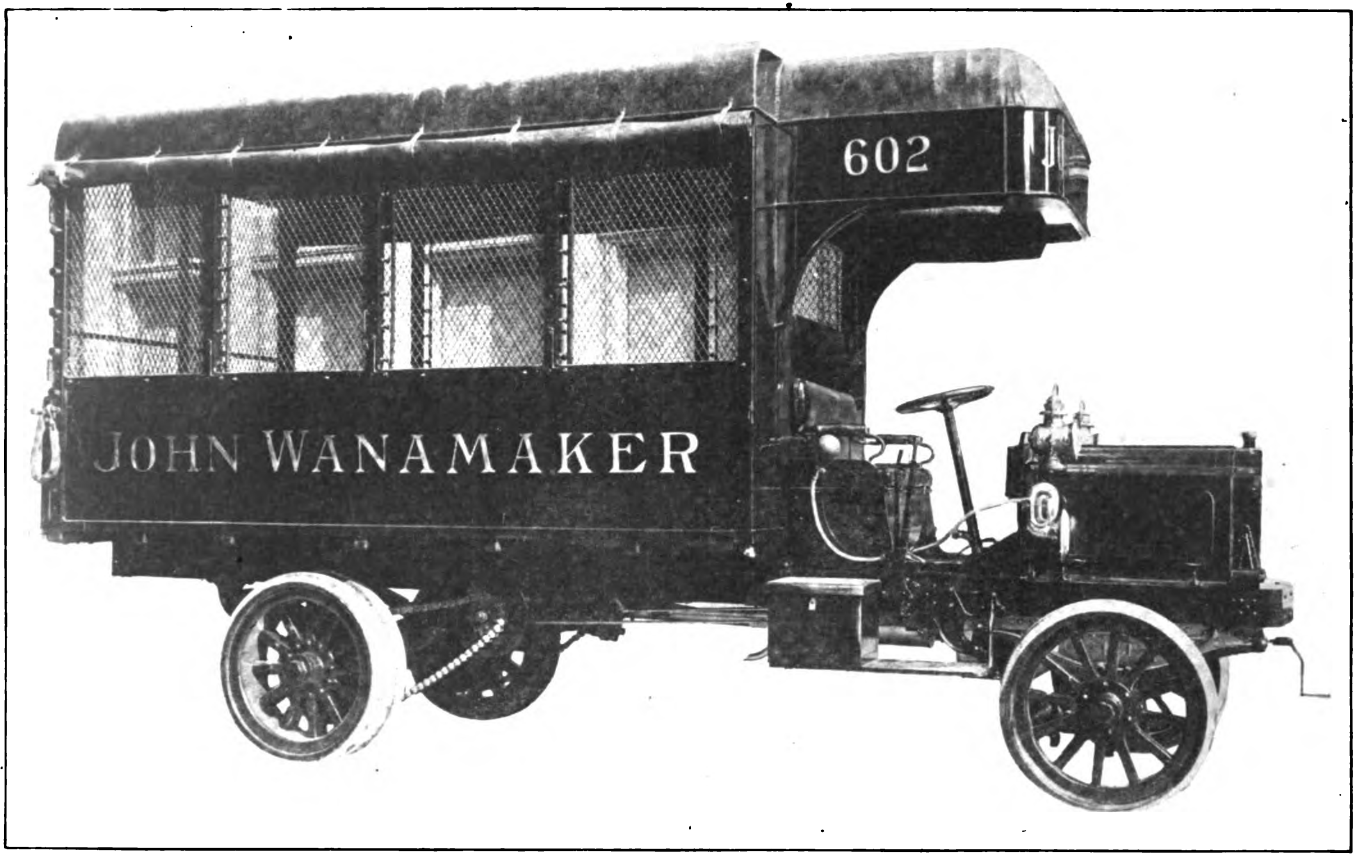
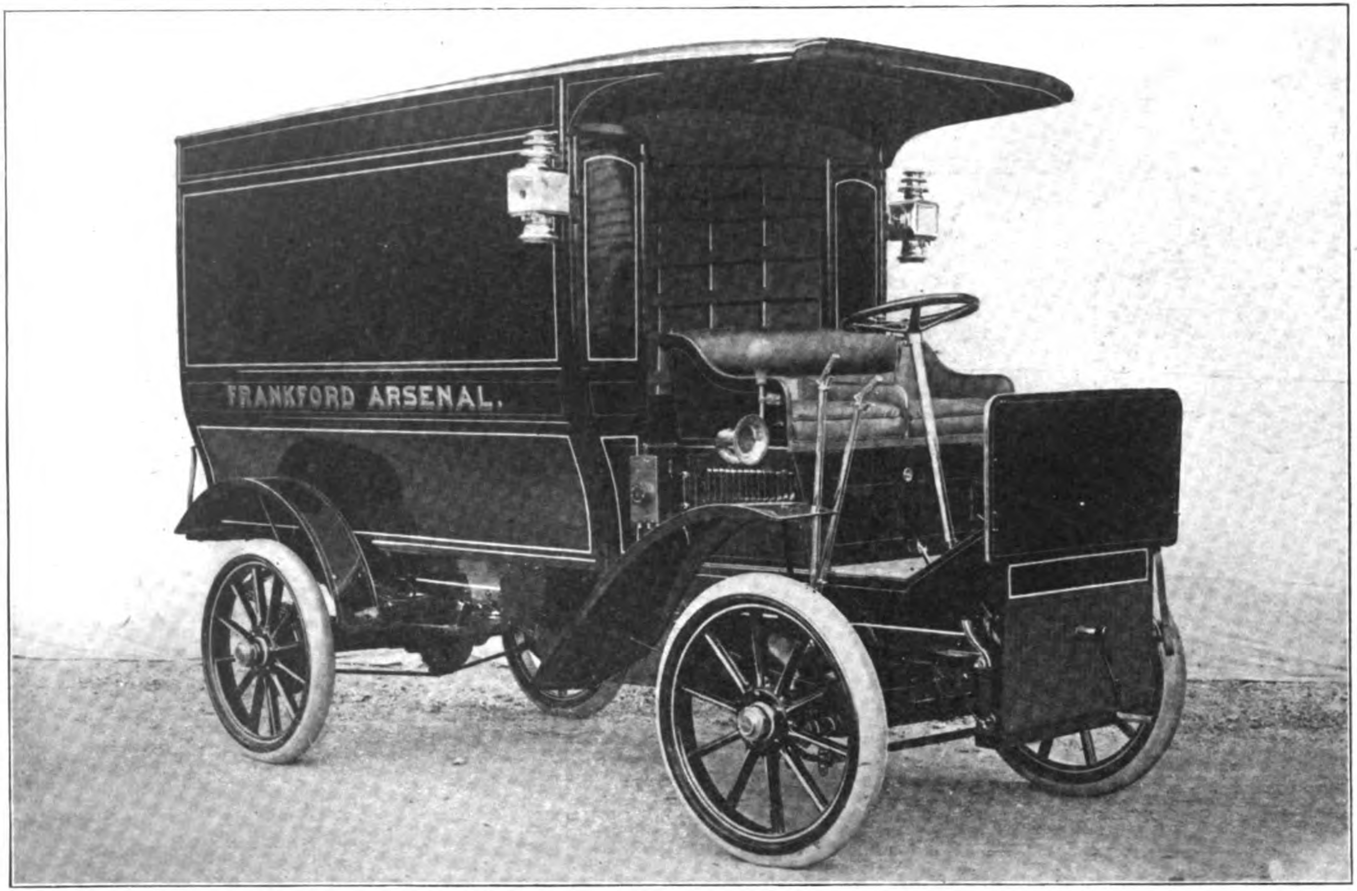


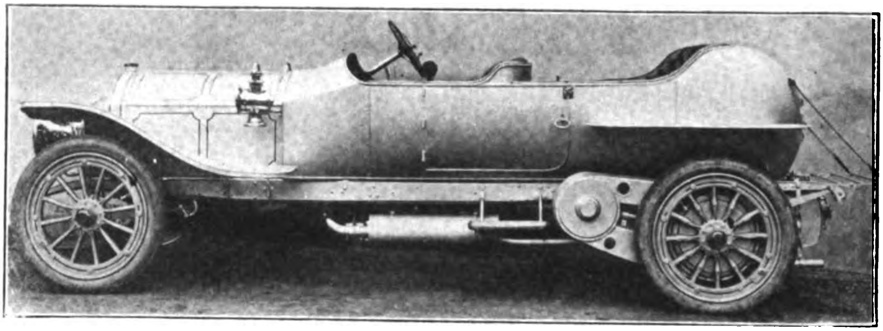
Fig. 112. Packard 3-Ton Truck Fitted with a Second or False Body to Facilitate Rapid Loading.

most convenient but most economical to rely upon the services of the public garage for storage, fuel, supplies, and ordinary repairs; it is also a wise precaution to refer any repairs of moment directly to the maker of the vehicle. But where the number of vehicles in the service of a house exceeds five or six, both greater economy and greater efficiency of the service will result from placing them under the care of a competent manager in a garage maintained by the establishment itself. Supplies of fuel and lubricating oil may then be purchased on more favorable terms and a closer check kept on the quantity used by the different cars. Closer check can also be kept of the drivers and their ability to handle the machines.

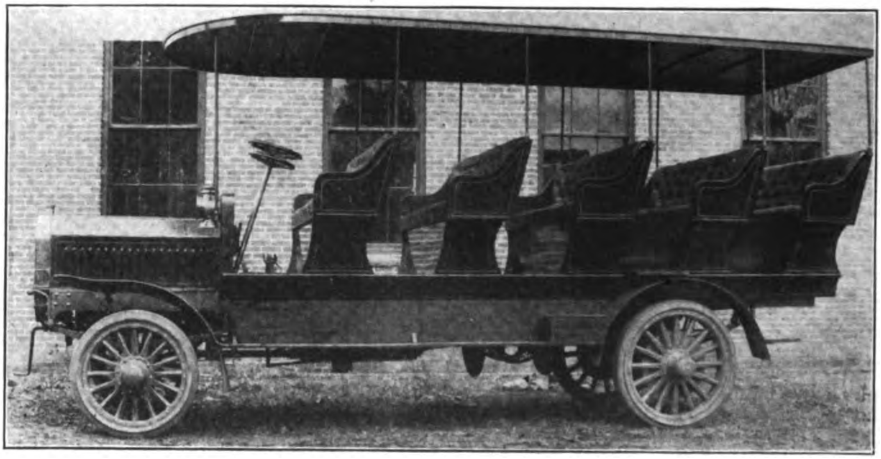
When a comparatively large number of vehicles is to be maintained, the economy and efficiency will be increased by the equipment of a garage, and a machine shop which is able to take care of the ordinary repairs and provide ample facilities for giving the machines the thorough overhauling to which they should be subjected at least once a year. Motor wagons are so far in advance of horse delivery, even where the latter has been brought to the highest degree of efficiency, as to admit of no comparison whatever. But as the cars are usually purchased by laymen and operated by unskilled labor, many disappointments result from expecting entirely too much. No matter how close an approach to mechanical perfection a machine may represent, it can never be anything but a machine. Those who condemn the commercial motor vehicle after a short trial which, from the user's point of view, has been marred by petty defections of the mechanism, seldom stop to think of the constant care and inspection involved in the up-keep of any machinery.



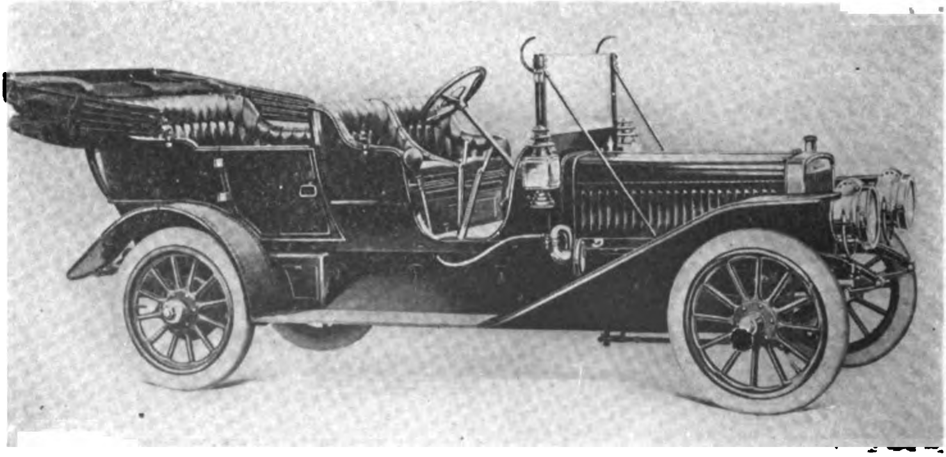
AUTOCAR DELIVERY WAGON IN THE UNITED-STATES SERVICE
Autocar Company, Ardmore, Pa.



GERMAN MERCEDES WITH TORPEDO BODY OF ENGLISH WORKMANSHIP; 65 H.P.
The Very Globular Stern is Used for Storage Space.



PLYMOUTH FRICTION-DRIVE, FORTY-HORSE-POWER, TWENTY-PASSENGER BUS
Commercial Motor Car Company, Plymouth, Ind.



THE WINTON "SIX," FORTY-EIGHT HORSE-POWER, TOURING CAR
This Car is Said to Hold the World's Upkeep Record of Seventy-Seven Cents per Thousand Miles. The Motor is Started by Compressed Air.

TYPES OF AUTOMOBILES

EVOLUTION OF PRESENT TYPES

The evolution of the automobile considered as a mechanism, and its development as a vehicle of transportation, have been so closely related that it would be impossible to separate them. The early conception of the vehicle was as crude as the early notions of the mechanism required to propel it. Both in France and Germany—where the modern automobile originated—and in this country the first attempts were "horseless carriages." Like the early railway coaches, they were copied after horse vehicles as closely as possible. The motor, usually of one, but sometimes of two cylinders, was stowed away under the body, and transmitted power to the rear axle through gears and individual clutches, with usually a sprocket chain as the final drive. To avoid the inconvenience of flexible transmission, the power plant was sometimes mounted on a rigid under-frame attached directly to the axles, where its unsprung weight had the natural result of pounding both running gear and machinery to pieces in short order.

The first impulse toward the now accepted standard of design came from France. Realizing the inconvenience of attempting to work on a motor half buried in the body, the French builders transferred it to the most accessible of all locations—in front of the dashboard; and they located the transmission gear in the next most accessible place, *i. e.*, under the footboard. They supported the power plant and the body on the same frame and springs, and transmitted power to the rear wheels, first through two sprocket chains, and later through a jointed shaft and bevel gears enclosed in the rear axle. From that time dates the recognition of the automobile's distinctive characteristics as a road locomotive rather than a horseless carriage, and the mechanical appearance, though first disliked, was soon conceded to be in keeping with the essential characteristics of the vehicle.

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Together with the "motor-front" type of design, the French introduced the sliding-gear transmission. On account of the higher degree of skill necessary to operate it, this transmission made slow headway in America at first, but its advantages have long since been recognized as outweighing its drawbacks, except for women operators and extreme amateurs.

With the front motor and the sliding gearset came the tonneau. At first the tonneau was entered from the rear, but improved frame construction and lengthened wheel base soon made possible the universal side entrance of today. Recently the tendency to enclose the passengers has taken another step in the torpedo or gunboat bodies now coming into vogue.

Side by side with the tonneau or touring car were developed a class of small, inexpensive runabouts for two passengers. The first had single-cylinder engines and planetary transmissions with single-chain drive. These were followed by runabouts which were miniatures of the larger cars, except that the motors had but two horizontal opposed cylinders. These, in turn, are being succeeded by four cylinder runabouts, but the transition process is not yet complete, and the most recent examples of this class exhibit a wide diversity in motor and transmission design.

A third class of cars has been developed, combining the limited passenger capacity of the runabout with the power and speed of the touring car. These roadsters carry normally two passengers, but sometimes have supplementary seats for one or two more. Starting with the same chassis as the touring car, many of them now have a specially designed chassis considerably lighter than touring-car construction requires.

For winter use various styles of closed bodies have been fitted to touring cars, and from the heavy limousines and landaulets has been evolved a new type of small, closed car for town use. From the town car, in turn, the taxicab has developed by simple standardization of construction and the adoption of extra large tires and heavy springs.

The automobile was once wholly a fair-weather vehicle. It is still such where mere pleasure is concerned, but physicians and other business and professional men now find in it an all-the-year vehicle whose traveling ability greatly exceeds that of the horse, and which can be used in any conditions except deep snow. Side doors or aprons for the front seats, wind shields for the dashboard, folding cape cart hoods for the top, and storm curtains and aprons enable the occupant to drive in any weather without personal discomfort. Easy riding is conferred by long and carefully proportioned springs, and security on slippery roads by chains readily attached and detached as desired. Tire troubles, once the motorist's bugbear, are minimized by better construction and by the use of larger sizes of tires, as well as by the quick detachable and demountable rims now almost universally used in one form or another.

In its economic aspect the automobile has undergone as great a change as mechanically. The early cars were short-lived because their construction was unequal—good at some points, bad at others. The busy owner of any but the smallest type of car needed a chauffeur to keep it in order. The small, low-priced runabouts gave good service according to their day and time, but wore out quite as rapidly as the larger cars.

Today any high-grade car, even of high power, requires so little grooming other than ordinary cleaning that its owner may dispense with the chauffeur. Roadside repairs are limited to tire replacements, and such ordinary work as is needed in the garage can be done by the handy man under the owner's instructions. Once a year the car needs a good overhauling, but even this costs little compared with what it used to, as many parts, *e. g.*, the transmission gears and bearings, and the engine and clutch bearings, may last two or three years before renewal is necessary.

As much as this cannot be said of the cheaper cars. The most striking feature of the automobile situation today is the great increase in the number of cars whose prices range from $500 to $1,000 for runabouts and small roadsters, and from $1,250 to $1,800 for small touring cars. The runabouts in this class are mostly of 10 horse-power to 15 horse-power, and the touring cars have four-cylinder motors of from 3¾-inch to 4¼-inch bore. Many of these are produced in response to a demand for an automobile at the lowest possible price and are too cheaply built to last long; others, while not in the high-grade class, may be called *triumphs of manufacturing ingenuity* when their prices are considered.

These new, low-priced cars are not intended to require the services of chauffeurs. It cannot be said that in this particular they are superior or even equal to the higher-powered, high-grade cars, but they are certainly superior to the average car of like power of a few years ago. They are less trappy and require far less watching and tinkering. Most of their lubrication is automatic; the ignition and carburetion seldom give trouble; the working parts are efficiently protected against dust and mud; and all parts from the radiator to the brakes are better proportioned, less liable to break or come loose, and far more durable than their prototypes. The average $1,500 car today is as good as the $2,500 car of four or five years ago, and, if not more durable, it is in many respects more consistent and reliable in performance.

ELECTRIC VEHICLES

The easiest automobile to drive, and the simplest mechanically, is the electric. If its range of action equalled its ease of running, it would certainly be preferred to every other type of car. In fact, however, its sphere is limited chiefly to local uses, where no greater mileage than 20 to 30 miles per day is ordinarily required. It is very popular in the city as the equivalent of the horse-drawn brougham and park runabout. Physicians find it eminently suitable for making local professional calls, and closed electric vehicles are preferred for shopping, calling, and visits to the theater.

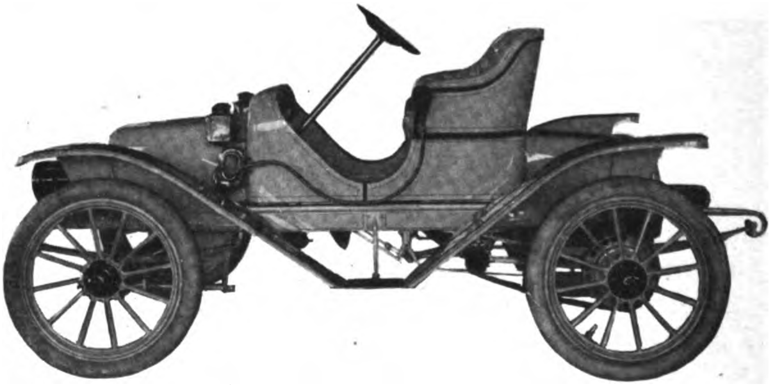


Fig. 1. Columbus Electric Runabout.
Columbus Buggy Co., Columbus, Ohio.

The open types of electric vehicles usually seat two passengers.

They are made with stanhope, victoria, and piano-box bodies, and contain usually 24 or 26 cells of battery—Fig. 1, Fig. 2, Fig. 3, and

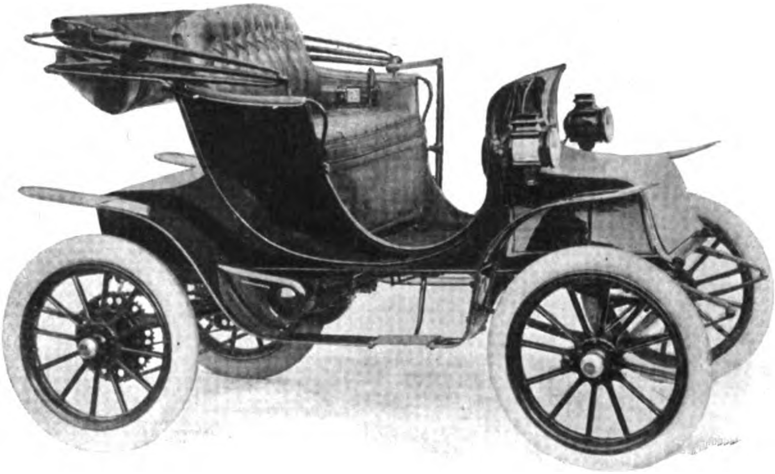


Fig. 2. Columbus Electric Phaeton.

Fig. 4. It was formerly the practice to attach the motor rigidly to the rear axle, but in present vehicles it is always hung from the frame, or else attached rigidly thereto. In the latter case it drives the rear axle either through a single-reduction gearing and sprocket chain or through a propeller shaft with universal joints, after the manner of gasoline vehicles.

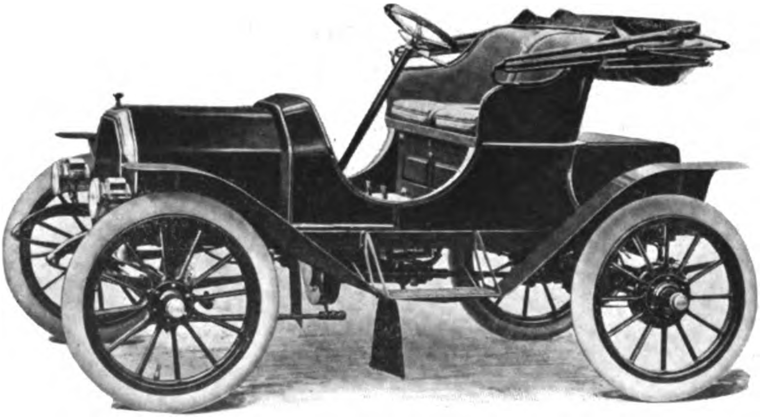


Fig. 3. Baker Electric Runabout.
Baker Motor Vehicle Co., Cleveland, Ohio.

The wheel base of these small cars is from 70 inches to 80 inches. The wheels are usually 30 inches or 32 inches in diameter, and the motor is rated at from 3 horse-power to 4 horse-power. The controller is usually of the series-parallel type, and gives four to six forward speeds and one or two reverse speeds. The motor, differential, and wheel bearings are lubricated by oil wells, and usually two sets of brakes are furnished. The body has a folding top for stormy weather.

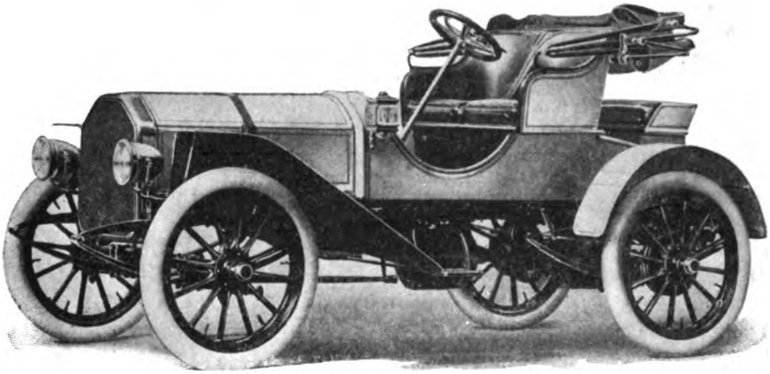


Fig. 4. **Baker Electric Roadster.**

Ascending the scale of size, a few roadster models of longer wheel base and larger battery capacity than the runabouts just mentioned may be found. According to size, these have from 24

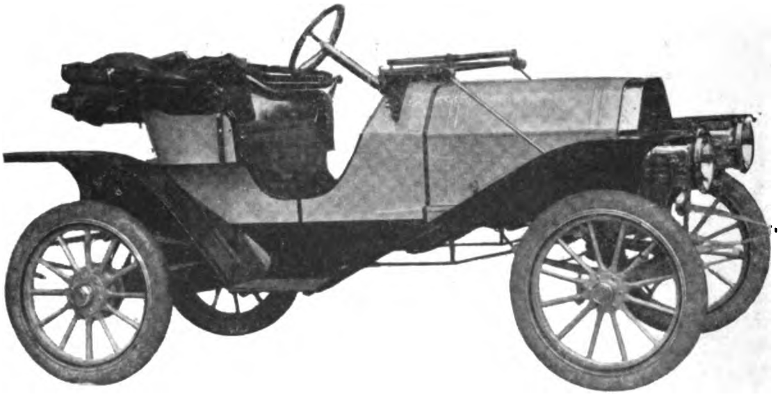


Fig. 5. Waverley Roadster.
Waverley Co., Indianapolis, Ind.

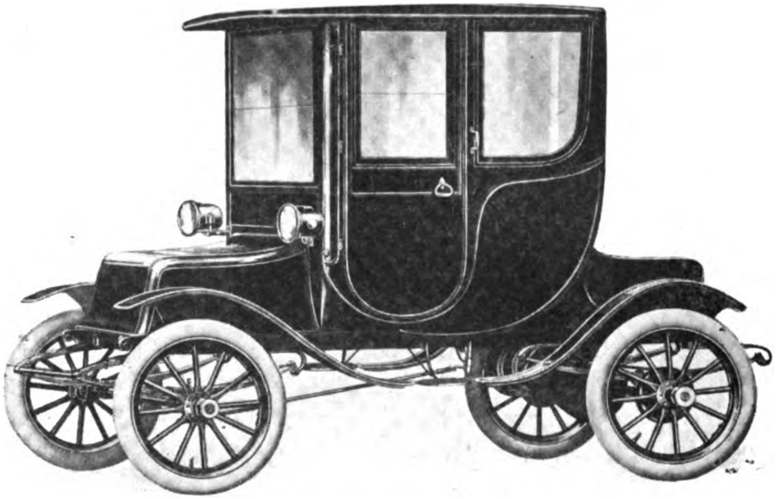


Fig. 6. Detroit Electric Coupé.
Anderson Carriage Co., Detroit, Mich.

cells to 42 cells, and the larger ones bear a close resemblance to gasoline touring roadsters. Mechanically they are enlarged editions of the smaller machines, Fig. 5.

The large class of enclosed electric vehicles begins with small

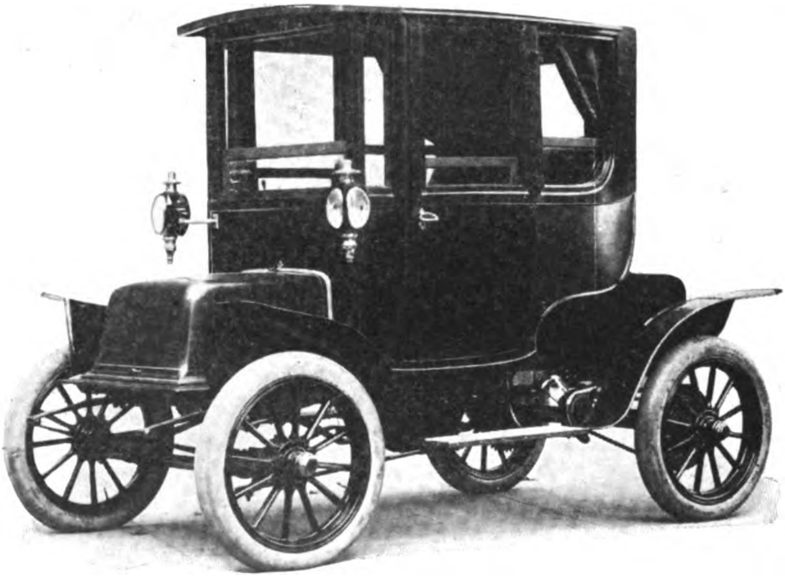


Fig. 7. Babcock Electric Town Car.
Babcock Electric Carriage Co., Buffalo, N. Y.

coupés with 24 cells to 30 cells, and extends upward to heavy town cars with 42-cell batteries. The small cars, Fig. 6, seat two passengers and have inside control. Larger ones of brougham type seat three, four, or five persons, and, like the coupé, have inside control so that the owner may do his own driving, Fig. 7. The large town cars are similar to the limousines and landaulets in the gasoline field, and have the driver's seat in front of the closed portion of the body.

STEAM CARS

Stanley. Of steam automobiles, there are at present only three active manufacturers in the country. Of these, the Stanley Motor Carriage Company builds light runabouts and one larger car which may be called a *touring car*, though not intended for heavy touring, Fig. 8 and Fig. 9. The boiler is located ahead of the dashboard, and the engine is supported somewhat like the motor of an electric vehicle, with the crank shaft geared to the rear axle, and the forward or cylinder end of the motor spring-supported from the body of the car. This relieves the axle and rear tires of a considerable portion of the dead weight of the engine.

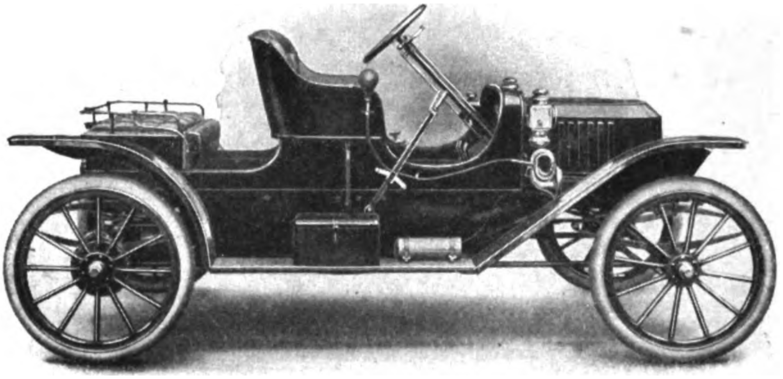


Fig. 8. Stanley Steamer Runabout.
Stanley Motor Carriage Co., Newton, Mass.

Lane. The Lane cars, Fig. 10, are of the heavy type for four or five passengers. The boiler is in front, and the engine behind it under the footboard, with sprocket-chain drive to the rear axle.

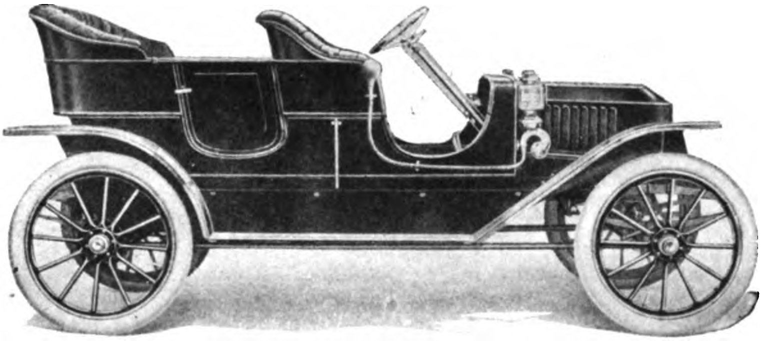


Fig. 9. Stanley Touring Steamer.

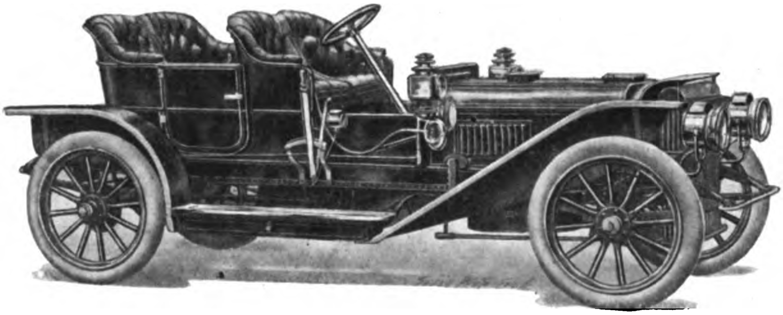


Fig. 10. Lane Touring Steamer.
Lane Motor Vehicle Co., Poughkeepsie, N. Y.

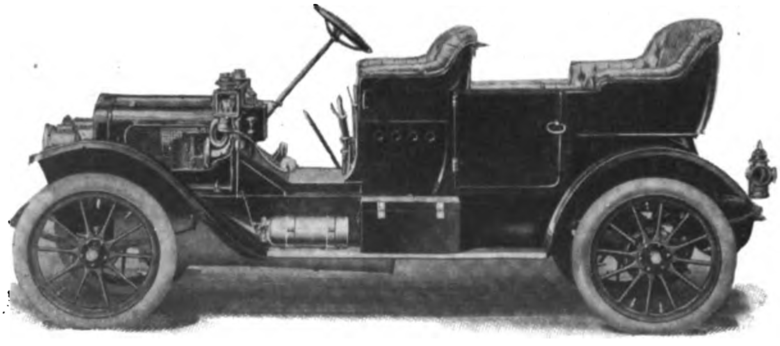


Fig. 11. White Steamer.
White Co., Cleveland, Ohio.

White. The well-known White steam cars are made in two chassis models of 20 horse-power and 40 horse-power respectively, Fig. 11 and Fig. 12. The flash generator is under the front seat, and the engine is under the hood in front. The smaller car is made in touring, runabout, and limousine bodies. The wheels are 32 inches in diameter with 4-inch tires, and the wheel base is 110 inches. The larger car is made in touring, roadster, and toy tonneau bodies, also with seven passenger limousine and Pullman bodies. It is a large and heavy car of 122-inch wheel base with 36-inch wheels.

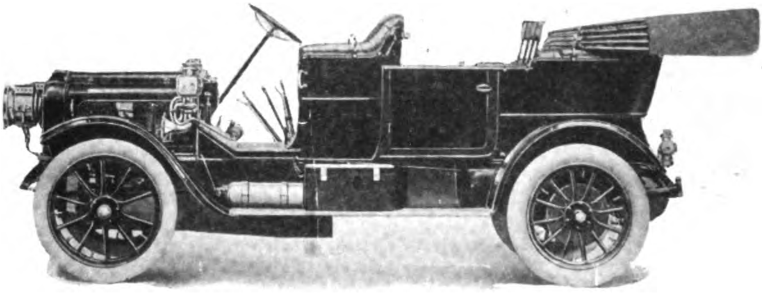


Fig. 12. White Touring Steamer.

GASOLINE CARS

MEDIUM-PRICED CARS

To understand clearly the present classification of gasoline automobile types, let us begin with what may be called the conven-

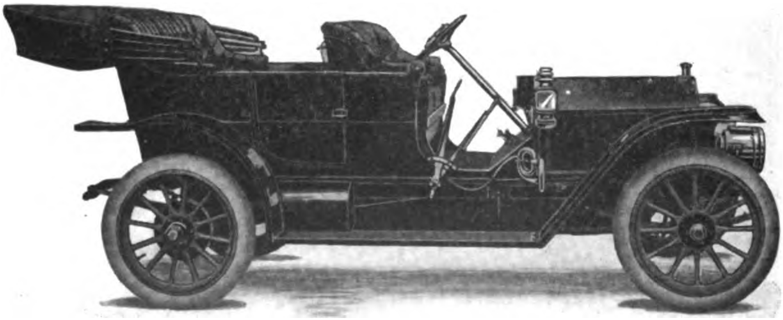
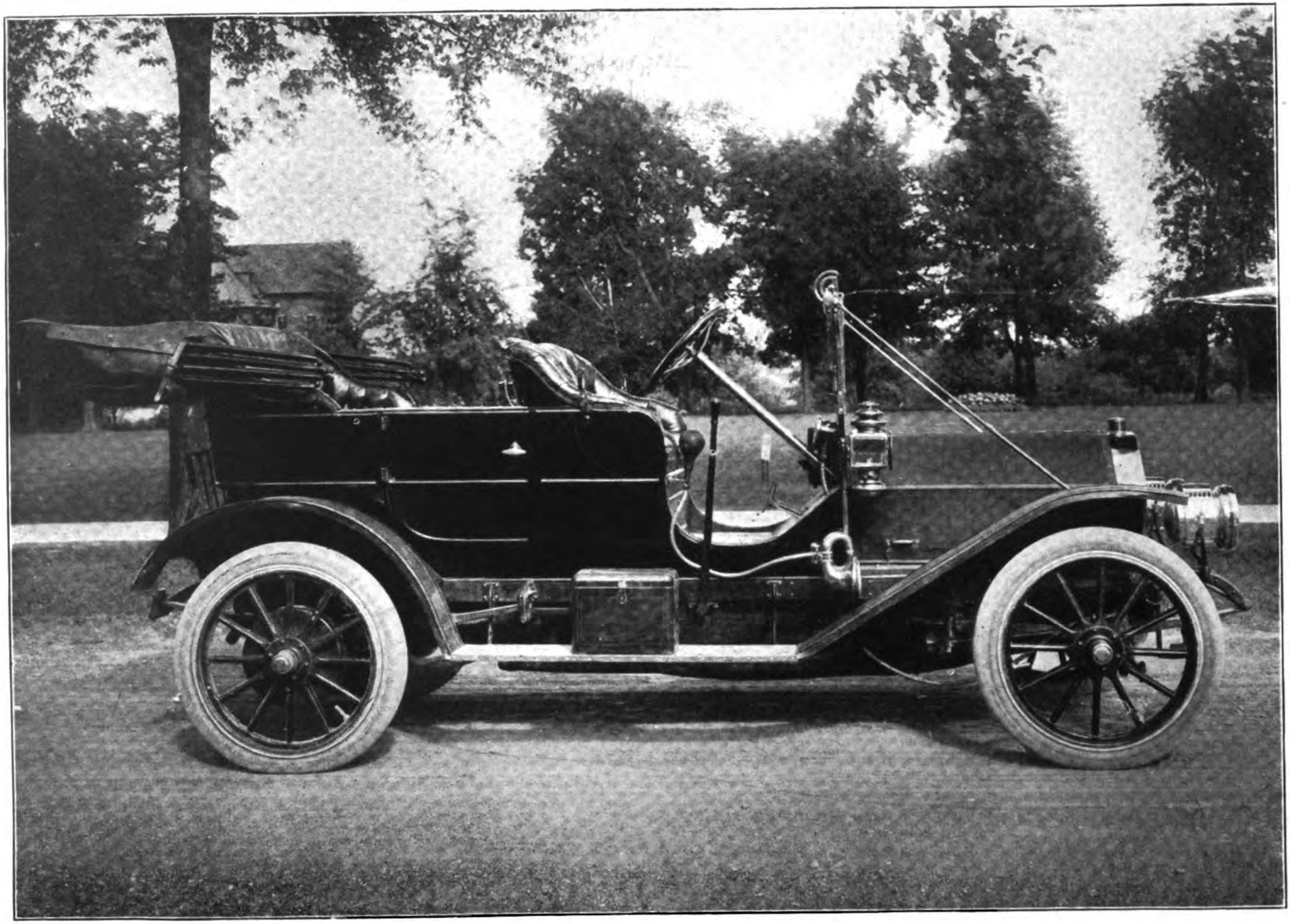


Fig. 13. Pullman Touring Car.
York Motor Car Co., York, Pa.



CARTERCAR THIRTY-HORSE-POWER, FIVE-PASSENGER TOURING CAR
Friction Transmission. Chain-in-Oil Drive. No Starting Crank is Used, the Motor Being Started by the Large Pedal to be Seen in Front of the Driver's Seat.

tional or standard type of touring car of medium power and price, Fig. 13 and Fig. 14. The cheaper and smaller types of cars are, with some few exceptions, developed from the standard type by reduction of size and simplification of parts. On the other hand, the cars of higher power and price show greater refinement and attention to detail. By bearing in mind precisely what the standard type is and what it will do, the beginner may estimate with reasonable accuracy what he may expect for his money in purchasing a cheaper or more expensive car.

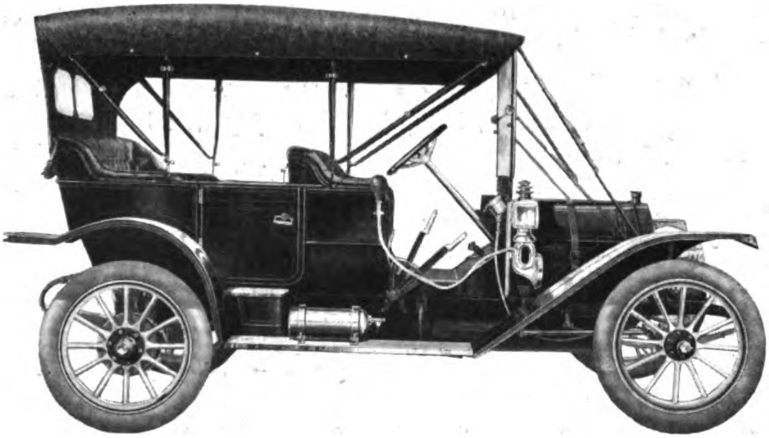


Fig. 14. Haynes Touring Car.
Haynes Automobile Co., Kokomo, Ind.

The standard type of medium-power car will have substantially the following specifications:

Motor, 4 cylinders cast in pairs. Bore, 4¼ inches. Stroke, 4½ inches. Rated horse-power, 30. Crank case, aluminum, supported from upper half; lower half of crank case forms a removable oil pan. Valves located on opposite sides of the cylinders.

Ignition by magneto, either of high-tension type or low-tension with step-up coil.

Cooling by water circulation with centrifugal pump.

Clutch, conical, leather-faced (or may be disk type, either metal to metal running in oil, or dry plates faced with woven asbestos).

Transmission, sliding-gear type, 3 forward speeds and reverse, with selective lever. Gear box located just behind clutch. Flexible joint between clutch and gears.

Final Drive through jointed propeller shaft and bevel gears. Rear axle floating or semi-floating type.

Running Gear, wheel base 108 inches for tonneau, 102 inches for roadster; wheels 34-inch diameter with 4-inch tires.

Springs, front, semi-elliptic; rear, three-quarter elliptic.

Brakes, emergency brakes acting on rear wheels; foot brakes acting either on rear wheels or on drum behind gear box.

Body, five-passenger tonneau, or roadster (three or four passengers). Other types: close coupled tonneau (four passengers), and landaulet or limousine geared low for town use.

Price, from $1,500 to $2,000 without wind shield. Magneto possibly an extra, but probably regular equipment. Weight of car 2,000 to 2,500 pounds without tools, water, or gasoline.

A car conforming to the above specifications cannot at this present writing (January, 1910) be thoroughly well built for much less than $2,000.

LOW-PRICED CARS

Let us now inquire by what means serviceable 30-horse-power cars may be built at prices ranging from $1,500 to $1,250. In order to reduce the cost of the motor which is the most expensive single part of the car, the bore is reduced to 4 inches, with probably 4-inch or 4½-inch stroke. In the car above described, the valves are located on opposite sides to gain flexibility at low speeds, since the spark plug is surrounded by fresh gas even when running closely throttled. The cheaper car has one or both of the valves opening directly into the cylinder head. This gives higher maximum power, but at some sacrifice of flexibility and quiet running. In many cases, however,

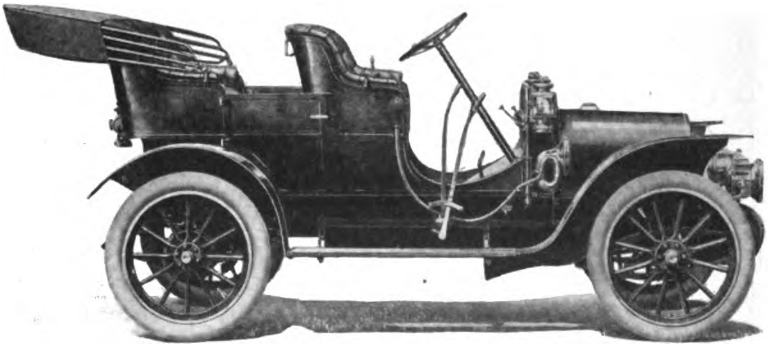


Fig. 15. Franklin Touring Car.
H. H. Franklin Mfg. Co., Syracuse, N. Y.

the valves are located together on one side, right or left, according to convenience. This eliminates one of the crank shafts, but requires the same bore as when the valves are opposite, or else higher speed with the smaller bore.

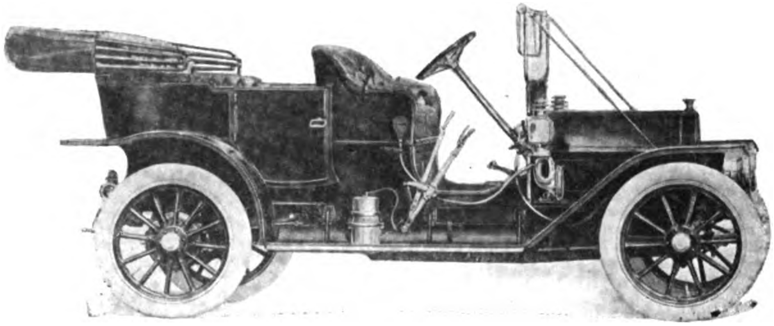


Fig. 16. Cadillac Touring Car.
Cadillac Motor Car Co., Detroit, Mich.

The cylinders, instead of being cast in pairs, may be cast *en bloc*, *i. e.*, all four in one casting.

The crank case may be of cast iron instead of aluminum, especially if the car is to sell below $1,500. In some cases the upper half is cast in one piece with all four cylinders, thus effecting a great saving of machine work with but a moderate increase in weight.

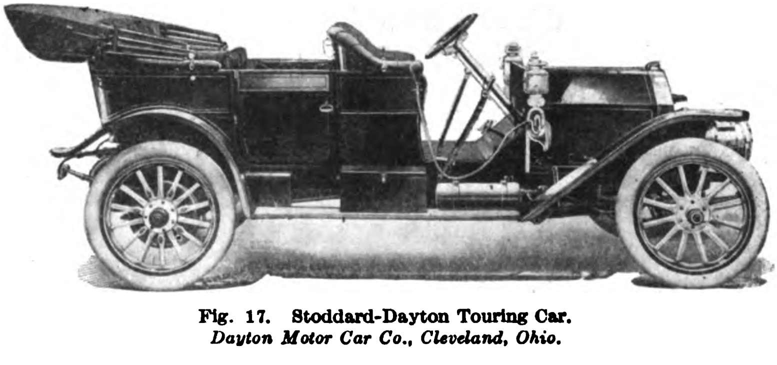


Fig. 17. Stoddard-Dayton Touring Car.
Dayton Motor Car Co., Cleveland, Ohio.

The ignition is probably by magneto, but a cheaper and therefore less reliable magneto is used. The radiator is cheaper and is likely to need replacement sooner.

The clutch is probably of the cone type without cork inserts.

The transmission is similar to the one above mentioned, but of cheaper materials. The bearings, instead of being high-grade roller or annular ball bearings, are likewise cheaper, and may be plain bushed. The rear axle is more cheaply constructed and the differential may be accessible only by disconnecting the axle from the wheels and taking it all apart. The above remarks regarding the transmission bearings apply to the rear axle also.

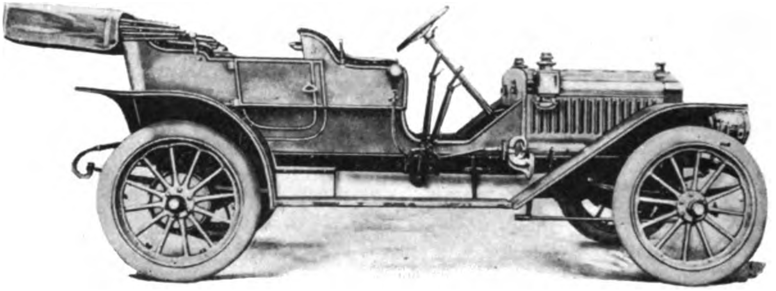


Fig. 18. Maxwell Touring Car—Detachable Tonneau.
Maxwell-Briscoe Motor Co., Tarrytown, N. Y.

The running gear will be about the same as above, but with possibly shorter springs and slightly smaller wheels. The axle may not be provided with a torsion frame, or if one is used it may not be hung to the best advantage. Throughout the car, money will be saved on materials, construction, and fittings in proportion to the lower price of the car.

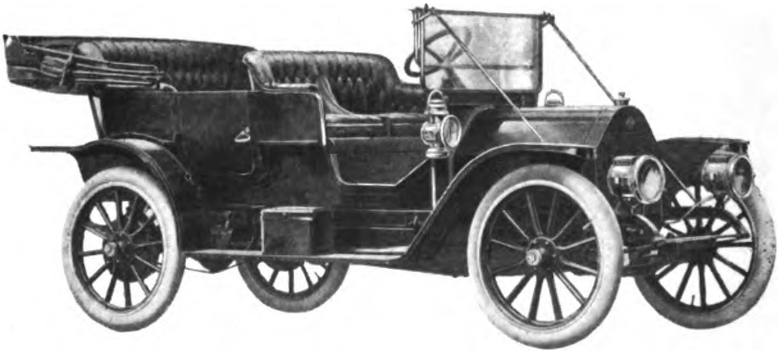


Fig. 19. Reo 35-H. P. Touring Car.
Reo Motor Car Co., Lansing, Mich.

Such cars as these are worth their price to one who does not purchase them with the idea that they will last as long or be as free from trouble as the higher-priced cars. In a sense, they are good cars for the beginner to "break in" on, since whatever damage they may suffer from abuse is less expensive than it would be if the car cost twice as much.

Some of the representative cars coming under this classification are shown in Figs. 15 to 19 inclusive.

Small High-Grade Cars. By reducing dimensions without reducing price, the quality of the product can be improved. There are a few cars of small power and high grade, having motors of about 3½-inch to 3¾-inch bore, whose construction is in every way up to the standard of the larger ones. These small machines cost about $1,500, and if the purchaser desired reliability and consistent performance rather than speed they are very satisfactory. They are easily handled by ladies, and are especially suited for town cars and for local suburban use. These cars, like the low-priced class just mentioned, are furnished with roadster and small tonneau bodies, and occasionally with closed bodies also. They have three-speed transmission and in mechanism, generally, are reduced duplicates of the larger cars.

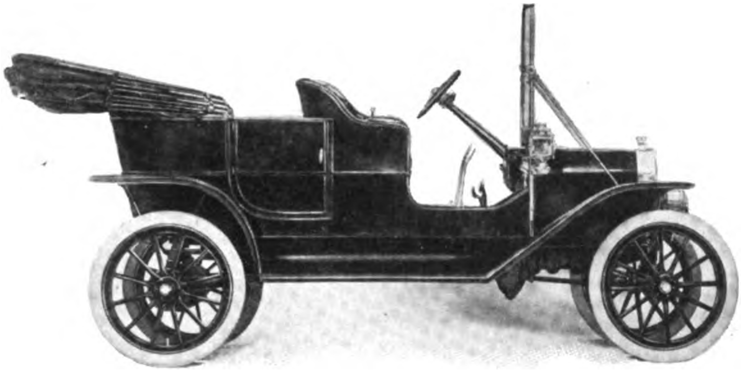


Fig. 20. Ford Touring Car.
Ford Motor Co., Detroit, Mich.

Cars for $1,200 or Less. (Figs. 20 to 26 inclusive.) When a selling price is $1,200 and under, it is no longer possible, at this date, to furnish a four-cylinder car with three-speed transmission. The motor also must be reduced; and accordingly motors are found of

3¾-inch and 3½-inch bore, with usually 4½-inch or 4-inch stroke. The cylinders are cast in one unit and sometimes integral with the upper half of the crank case. The valves, as a rule, are together on one side, to save the expense and complication of overhead valves in a small engine. Transmission is of the planetary type giving two speeds ahead and one reverse, by clutch and friction bands. The fan is omitted from behind the radiator, the flywheel spokes being formed to act as fan blades, and gravity (thermo-siphon) circulation is used or else a small gear pump is built into the engine. The springs, instead of being semi-elliptic, are in some cases front and rear cross springs, the axles being held parallel by radius rods.

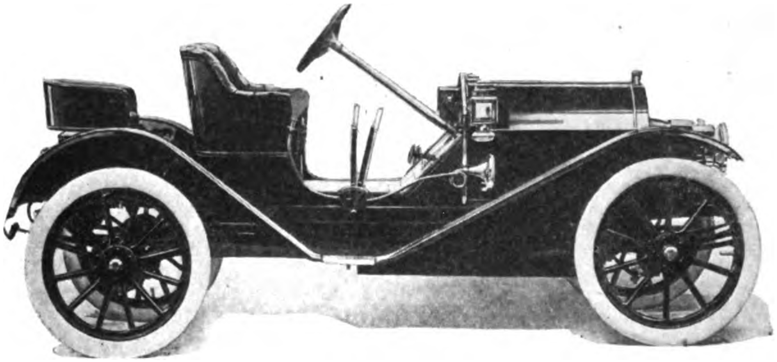


Fig. 21. Hudson Roadster.
Hudson Motor Car Co., Detroit, Mich.

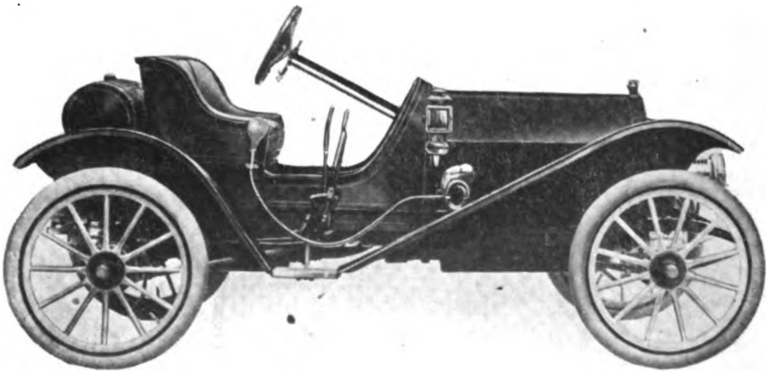


Fig. 22. Paige-Detroit Roadster.
Paige-Detroit Motor Car Co., Detroit, Mich.

Cars of the type just described have achieved a great popularity with owners who expect to use a car only one or two seasons and then dispose of it. They are light in build, very simple in mechanism, and are sold at a low price. Necessarily they do not contain the materials or workmanship of higher-priced cars, and they are rushed through the factory at a rate which precludes the possibility of much individual attention being bestowed on any given car. The purchaser must expect to watch for minor faults in ignition, carburetion,

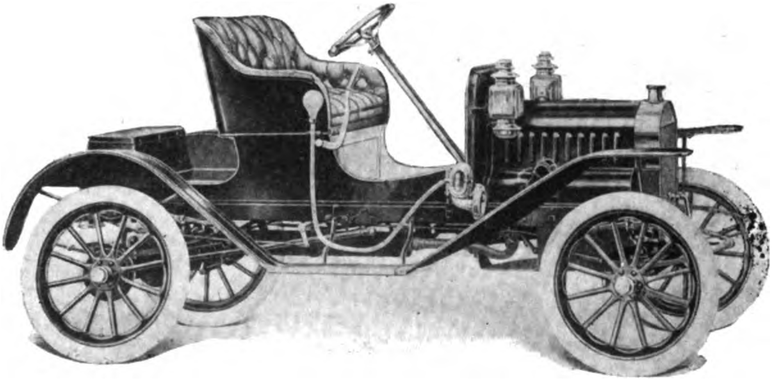


Fig. 23. Maxwell Runabout.
Maxwell-Briscoe Motor Co., Tarrytown, N. Y.

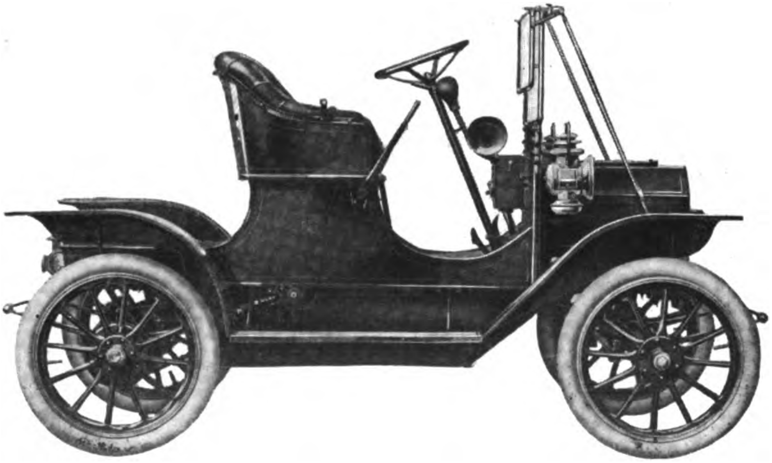


Fig. 24. Reo Runabout.
Reo Motor Car Co., Lansing, Mich.

and adjustment generally, and correct them as they appear. Nevertheless in intelligent hands these cars will run as much as 10,000 miles before needing anything of consequence in the way of repairs.

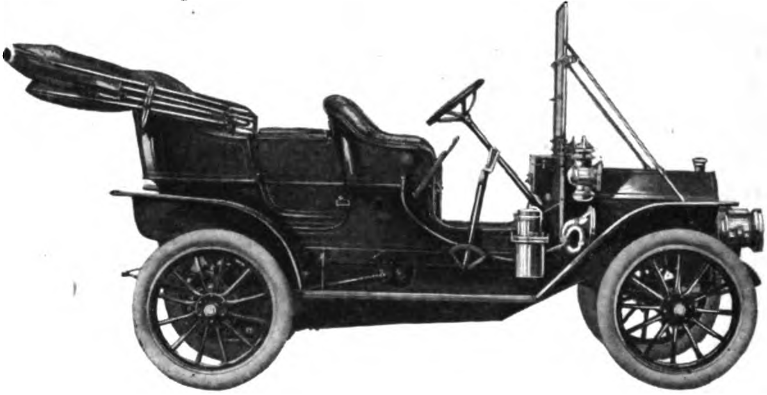


Fig. 25. Reo 20-H. P. Touring Car.

A planetary gear cannot to advantage give more than two speeds ahead, and it is very inefficient in any but the direct drive. This fact has led to the adoption recently of two-speed sliding gears in a considerable number of low-priced runabouts and roadsters selling for $800 and less. As it takes some skill to shift from one gear to another when the difference in ratios is as much as three to one—it has to be at least that when there are only two changes of speed—

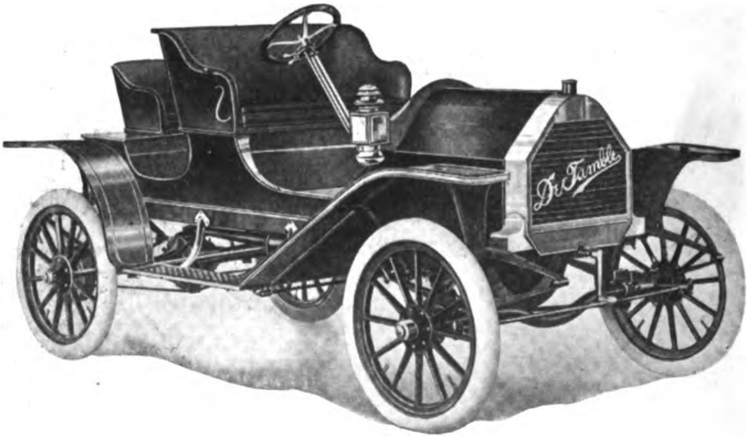


Fig. 26. DeTamble Runabout.
DeTamble Motor Co., Anderson, Ind.

and as the only advantage of such a gearset over planetary gears is more efficient performance in low gear, it seems doubtful if the advantages of these two-speed sliding gearsets compensate for their disadvantages. It is probable that in another year or two this type of transmission will entirely disappear, being succeeded by the standard three-speed type.

In other respects the runabouts and miniature roadsters just mentioned are quite attractive little cars. They are "sporty" in appearance, and have motors and running gear substantially duplicating those of the larger cars. The clutch is usually a leather-faced cone; drive is by propeller shaft; and other features are in keeping.

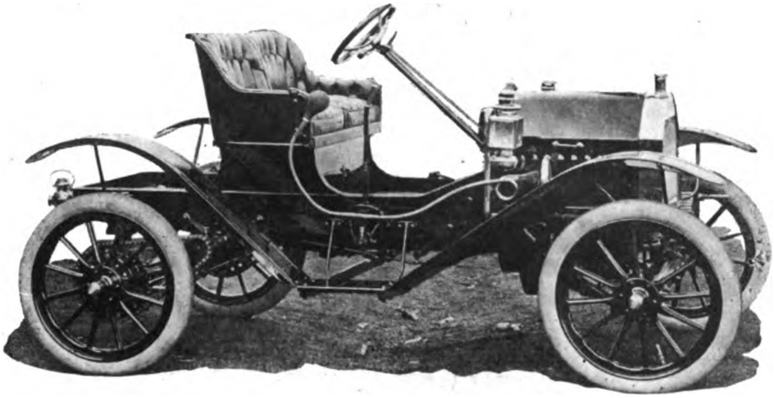


Fig. 27. Brush Runabout.
Brush Runabout Co., Detroit, Mich.

The wheel base is from 90 inches to 96 inches. Of course the mechanism is simplified to the utmost, and the construction is not such as to guarantee a longer life than about three seasons. As the cars are very light and are geared somewhat low, nearly all the running is done in high gear, this makes them easy for the novice, except for the single difficulty of shifting gears above referred to.

A little lower in the scale of price comes a small class of two-passenger runabouts whose motors have two horizontally opposed cylinders located crosswise under the bonnet. Some of these cars have planetary gears, others have two-speed sliding gears. Their chief usefulness is perhaps to give the beginner something with which to practice, but they are also useful for strictly short distance purposes, as one might use a bicycle or a horse and carriage for going about town, or to the railroad station.

Parallel with the class of cars just described, and dating further back in the scale of evolution, is an intermediate class of machines having two-cylinder, horizontal motors located fore and aft under the body, and developing usually about 15 horse-power. These cars are a development from the now obsolete small, single-cylinder runabout with horizontal motor. Like their early prototypes, they have two speeds, planetary transmission, and single-chain final drive. Owing to their mechanical simplicity one can get perhaps more in the way of power and travel ability for a given outlay in these cars than in any other type of automobile; but on account of the limitations of their two-speed transmission they are popular only with beginners and with women drivers, to whom the management of the planetary transmission is much easier than that of the sliding gears. They are good cars for local use and for rough work. They are not fast, and usually are built to sell at a low price, so that they are practically worn out in about three seasons.

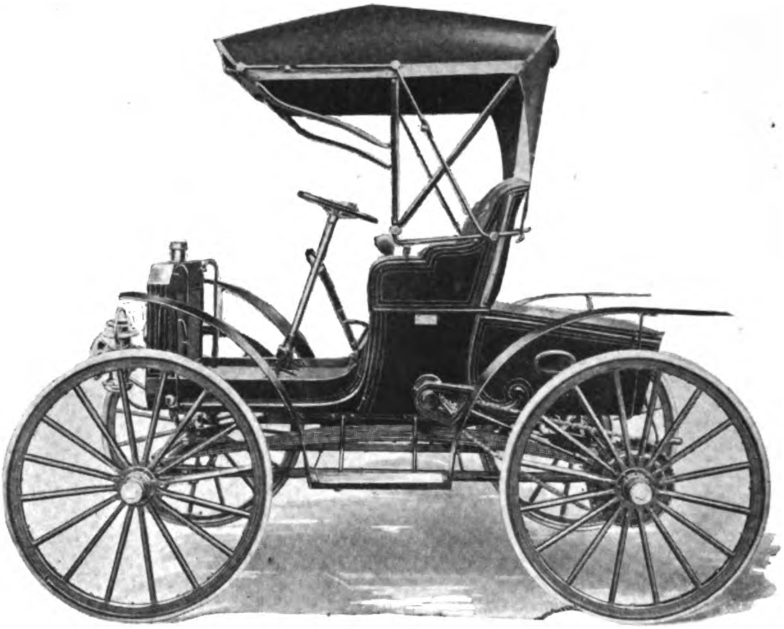


Fig. 28. Schacht Buggy Type.
Schacht Mfg. Co., Cincinnati, Ohio.

The small runabout illustrated in Fig. 27 belongs to no class, so individual is its design and construction. It has a single-cylinder, vertical motor in front, planetary transmission, and side-chain final drive from a cross shaft containing the differential. The motor is balanced by the unusual device of gearing a revolving counterweight to the crank shaft. The reciprocating parts are counterweighted on the cranks, and the revolving counterweight just mentioned balances the lateral inertia of the crank counterweights. The planetary transmission is enclosed in oil and has disk clutches for the low speed and reverse, as well as for the high speed, instead of the usual contracting bands. Instead of the usual leaf springs, whether half elliptic or otherwise, this machine has helical springs, and the axle ends are guided by short radius rods whose hinged ends bear against friction plates which act as shock absorbers. The chassis frame and the axles are of wood. The wheels are small. The whole machine is a good example of ingenious manufacturing to sell at a very low price.

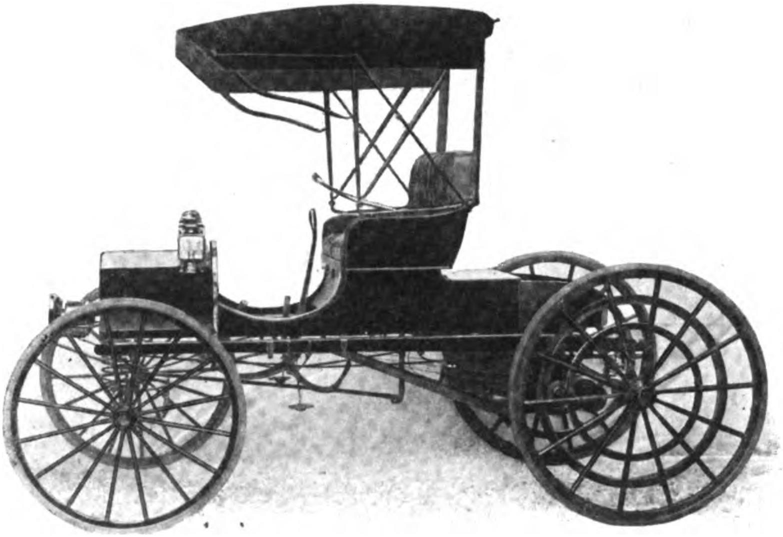


Fig. 29. Duryea Buggyaut.
Charles E. Duryea, Reading, Pa.

Buggy Type Machines. (Fig. 28 and Fig. 29.) One more type of low-priced machine remains to be mentioned. That is the so-called buggy type. These machines as a class are characterized, as their name indicates, by relatively high wheels—usually 42 inches diameter, with narrow, solid tires. The motors are as a rule horizontal, with two opposed cylinders, air- or water-cooled. The transmission is sometimes planetary, sometimes of the individual clutch type. The final drive is always by individual belts running over large rims attached to the spokes of the rear wheels. Sometimes there is not even a differential, but one belt is allowed to slip when a curve is negotiated. As these machines are at present in a transitional stage, nothing very definite can be said about their future. They have a certain popularity in farming districts, but for the most part appeal only to the man buying his first car. They are seldom carefully constructed, and they contain none of the engineering refinements of the standard types of automobiles.

HIGH-PRICED CARS

We may now turn to the other end of the scale and examine the types of cars which grade upward from the typical medium-priced car with which this section began.

As the scale is ascended, both in engineering quality and in horse-power, the tendency is more and more exclusively to use the "T head" motor, and usually the cylinders are cast in pairs. The crank case is aluminum, and usually a removable oil pan permits the crank-shaft bearings to be examined. Occasionally, however, the crank case is barrel shape, with removable heads at the ends and the intermediate bearings supported in removable pillow blocks

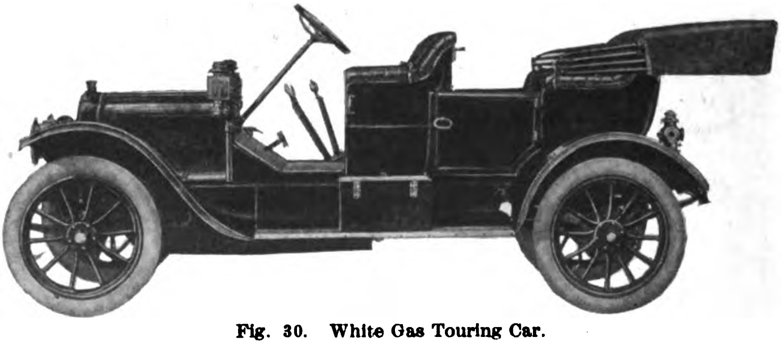


Fig. 30. White Gas Touring Car.
White Co., Cleveland, Ohio.

bolted in place through the bottom of the crank case. Ignition is by high-tension magneto, either with an entirely separate battery system sparking a second set of plugs, or with an auxiliary battery and coil, for starting only, sparking through the magneto distributor and the same set of plugs. The clutch is usually of the multiple disk type, either dry or running in oil, though special types of contracting or expanding band clutches are also used. The carbureter is hot-jacketed and is usually manufactured by the builder of the car.

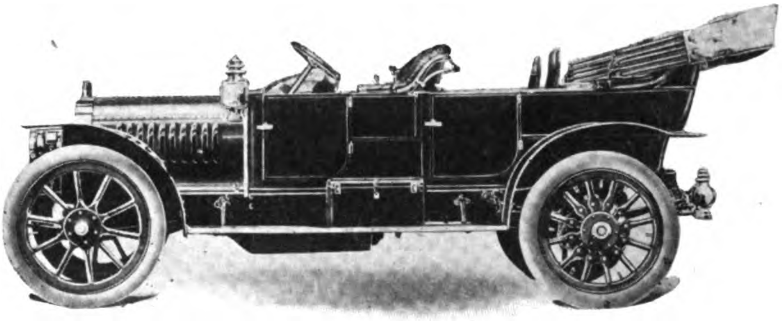


Fig. 31. Rainier Touring Car.
Rainier Motor Co., New York City.

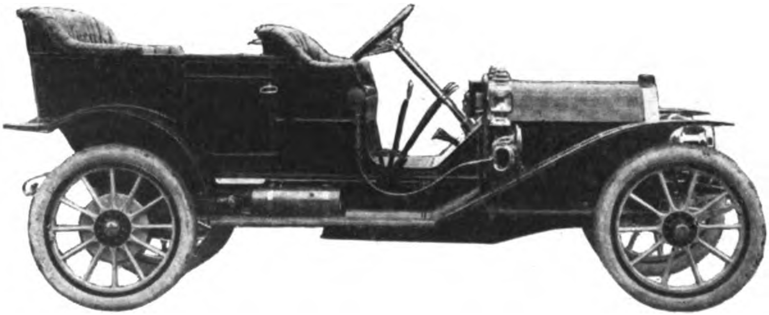


Fig. 32. Premier Touring Car.
Premier Motor Mfg. Co., Indianapolis, Ind.

The transmission gives either three speeds or four speeds, the latter being preferred for high powers and sometimes for medium powers and low powers also. Final drive is in some cases by side chains, but usually by propeller shaft. The rear springs are three-quarter elliptic or platform, and the rear axle, if shaft-driven, is of the floating type. The torsion frame and radius rods are in most cases carefully worked out, so that the springs have only vertical loads to carry; the propeller shaft has only its own proper work to do; and the radius rods, torsion frame, and springs do not conflict with each other in any way. Side sway is provided for by pivoting the torsion frame at its front end and also to the rear axle in order to permit side movement, and in a few of the best examples of construction the radius rods terminate in hardened ball and socket joints adjustable for wear. Minute attention is paid both to prevention of undue wear and to provision for easy replacement when wear occurs. The minor bearings of the steering gear, springs, gear and brake operating mechanism, etc., are usually hardened and bushed, and are provided with grease cups ensuring constant lubrication. Similar grease cups are in many cases found in the medium-priced and cheap cars, but the hardening and bushing features are apt to be omitted.

Illustrations of these cars are shown in Figs. 30 to 44 inclusive.

Six-Cylinder Cars. The six-cylinder car is conceded to be the high-water mark of excellence in automobile construction. Its advantages are as follows:

1. Complete absence of the mechanical vibration due to inertia and centrifugal force of the moving parts, since these are in perfect balance at all positions of the crank.
2. Smoother turning effort, due (*a*) to the individual impulses being smaller for equal power, (*b*) to the impulses overlapping.
3. Ability to run very slowly without "killing" the engine, due partly to the overlapping torque, but chiefly to the more regular and continuous suction on the carbureter.
4. Ability to accelerate quickly, due to the same causes as 3.

Some advantage accrues to the transmitting mechanism of the car as a result of the smoother torque of the six as compared with the four. Although it is perhaps too early to generalize on the subject, it seems probable that for equal power a six-cylinder car may be expected to outlast a four-cylinder car. On the other hand, a six-cylinder engine cannot be made very compact without some sacrifice of wearing qualities in the engine, owing to the reduced length of the crank-shaft bearings. The necessarily long wheel base requires heavier frame construction, and also increases somewhat the possibility of the flywheel rim striking obstructions in the road if the flywheel occupies its usual position at the rear end of the crank shaft. In a few makes of cars, that possibility is averted by locating the flywheel at the front end, though this certainly necessitates a stronger crank shaft.

The six-cylinder car made its way first in the higher powers, for the obvious reason that the vibration of a four-cylinder engine becomes objectionable when the bore is increased beyond five inches. The attractive riding qualities of the six-cylinder have, however, led to its adoption in engines of as small as 3½-inch cylinder bore, and developing about 25 horse-power. It is yet too soon to say to what extent the six-cylinder will be adopted in other than the highest-grade cars, but among the latter it seems to have a sure place.

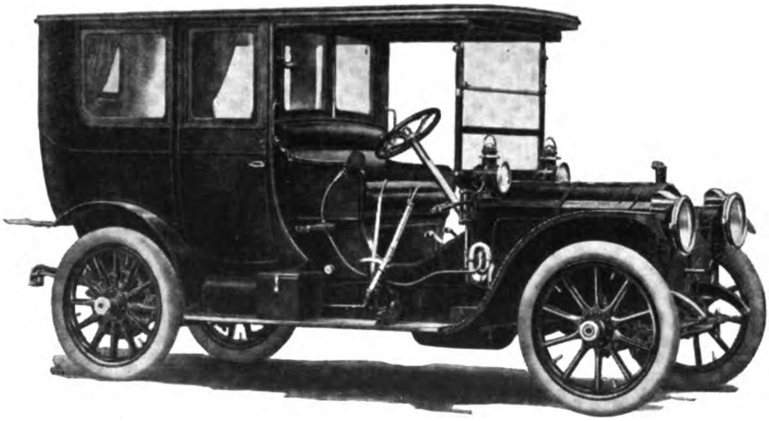


Fig. 33. Packard Limousine.
Packard Motor Car Co., Detroit, Mich.

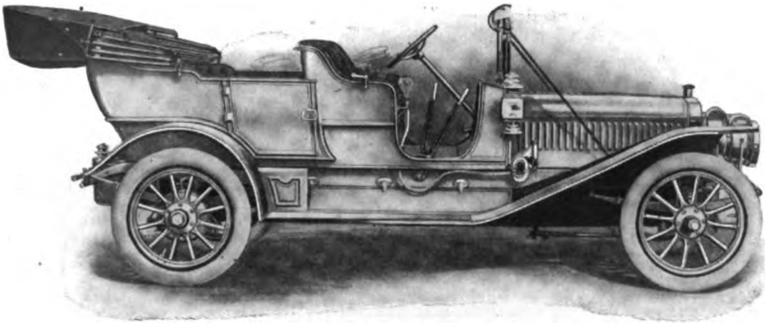


Fig. 34. Winton "Six" Touring Car.
Winton Motor Carriage Co., Cleveland, Ohio.

Bodies. *High-Powered Type.* In the choice of bodies the purchaser of a high-grade car has greater latitude of choice than is open when his price limit is below $2,000. Up to 30 horse-power or 40 horse-power, the standard tonneau car seats five passengers, with increasing foot room as the wheel base lengthens. In the higher powers the tonneau alone frequently seats five, the last two usually on folding seats, but sometimes on stationary swivel seats between which access is had to the rear seat. For owners who do not seek large carrying capacity, there are "close-coupled" and "pony" tonneaus, Fig. 35 and Fig. 36, seating in the rear two passengers only, and having the tonneau seat ahead of the rear axle, thereby adding to the passengers' comfort and also permitting higher speeds. For the motorist who usually takes but one passenger, but on occasion

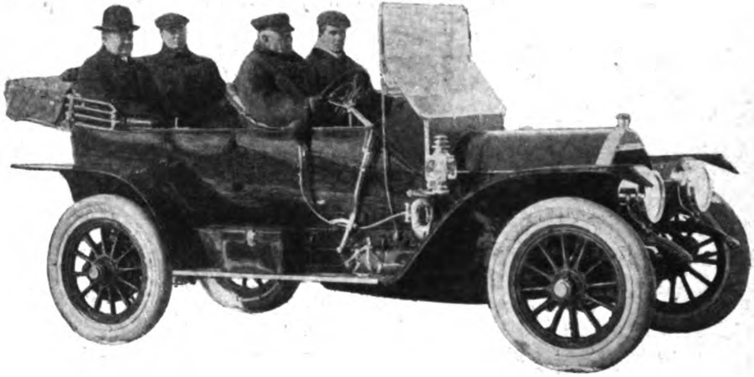


Fig. 35. Knox Touring Car.
Knox Automobile Co., Springfield. Mass.

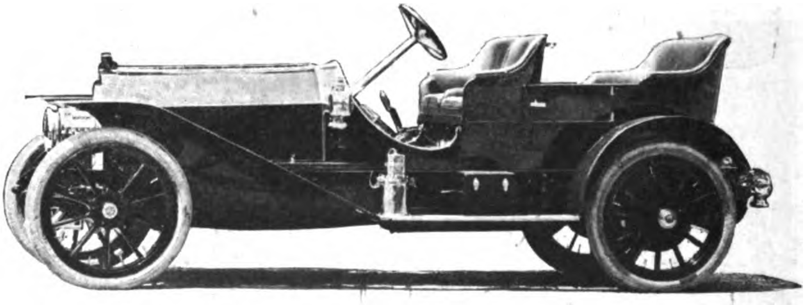
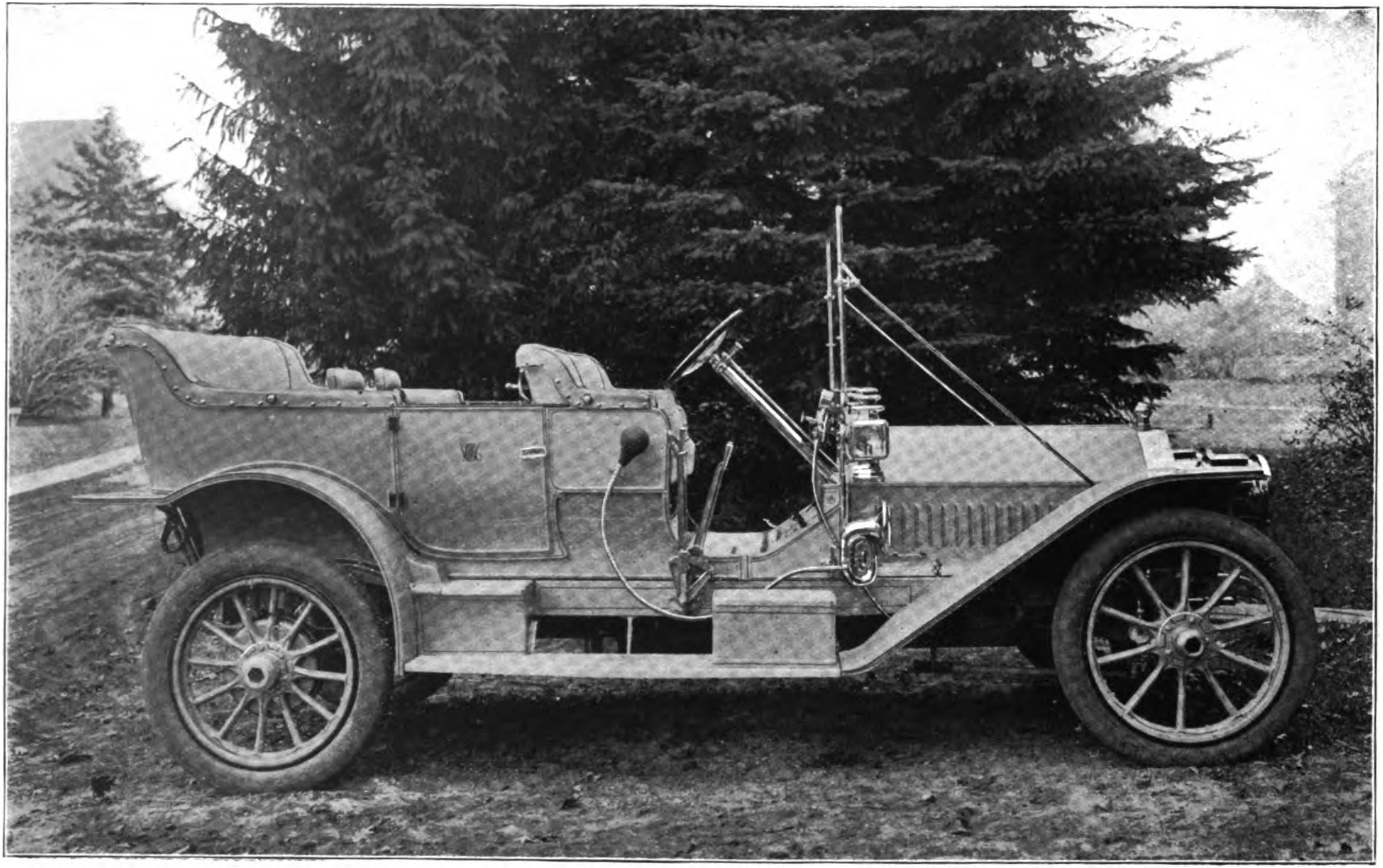


Fig. 36. Palmer & Singer Toy Tonneau.
Palmer & Singer, New York City.



OLDSMOBILE TOURING CAR WITH STANDARD EQUIPMENT
Olds Motor Works, Lansing, Mich.

may take one or two others, there are roadster bodies with single and double rumble seats. For strictly touring purposes the rear seats give place to the large permanent box or hamper wherein clothing and other touring supplies may be packed. This hamper is separate from the tool boxes.

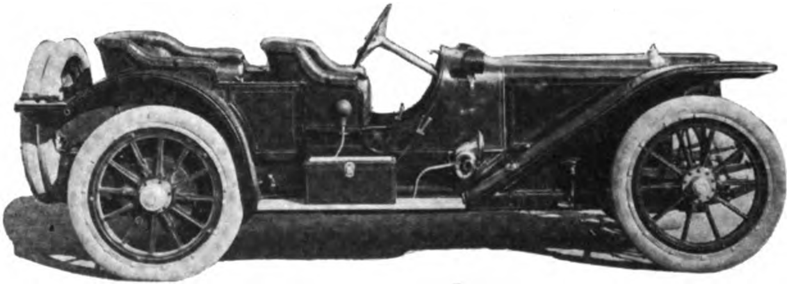


Fig. 37. American Traveler.
American Motor Car Co., Indianapolis, Ind.

In closed cars there is the limousine seating from three to five passengers inside and one beside the driver in front. The limousine, Fig. 33 and Fig. 41, is used chiefly for town and suburban work and as a depot conveyance in bad weather. The landaulet, Fig. 38, which has the rear seat covered by a leather or pantasote top which can be folded back, is preferred for summer use where enclosure is desired only in case of rain.

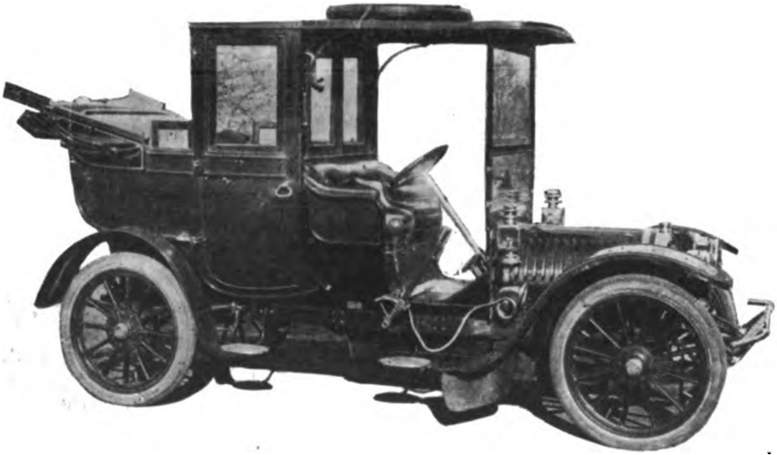


Fig. 38. Hotchkiss Landaulet.
Hotchkiss Import Co., New York City.

In addition to these there are numerous special styles of body, built usually to order, such as the Berline, an enlarged limousine.

Torpedo Type. Figs. 43 and 44. An innovation of the last two seasons is the torpedo or gunboat style of body, distinguished, first, by having the front or driver's seat enclosed in exactly the same manner as the tonneau, but with the door on the left side only; and, second, by the severe straight line effect of the body design, which is suggestive of the sides of a racing motor boat. Not infrequently a rounded tool hamper finishes off the rear of the tonneau, and by giving the displaced air a chance to come in smoothly it partially prevents the intense suction which raises so much dust.

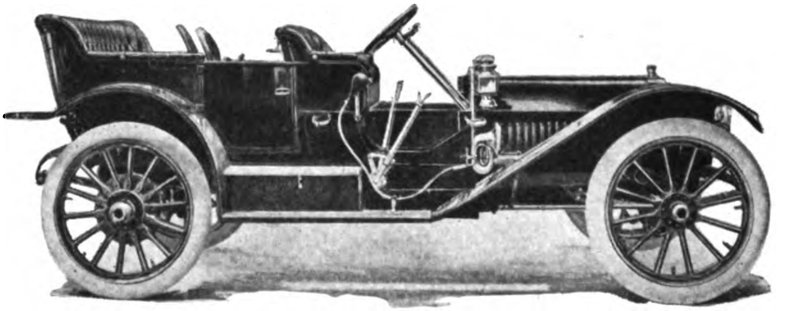


Fig. 39. Oldsmobile Touring Car.
Olds Motor Works, Lansing, Mich.

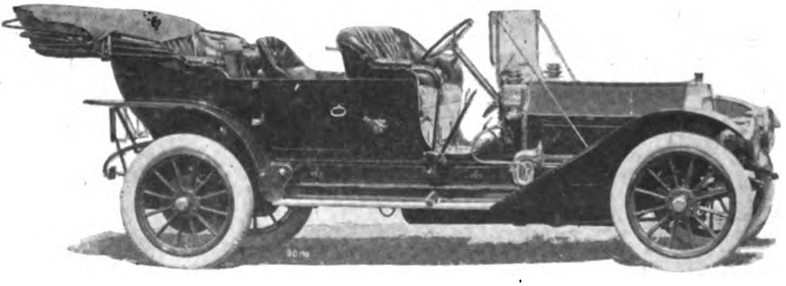


Fig. 40. Pierce-Arrow Touring Car.
Pierce-Arrow Motor Car Co., Buffalo, N. Y.

The advantage of the torpedo style of body is that it helps to keep the driver warm. It is nearly impossible and certainly dangerous for the driver to put a robe about his legs, and his only recourse is to wear fur or leather "overpants" and wool-lined overshoes. With a wind shield and with the sides of the seat closed in, these uncomfortable protectors become necessary only in severe weather.

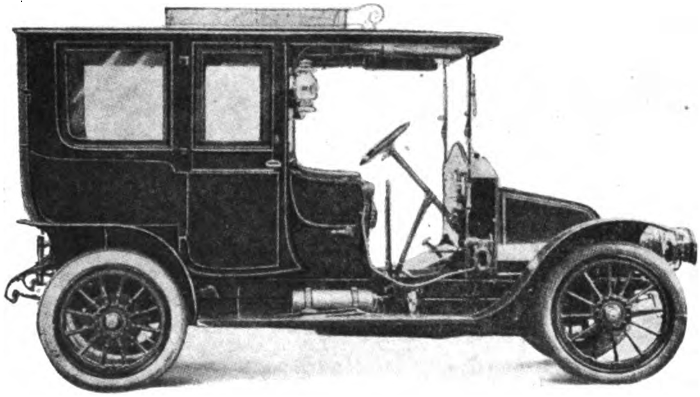


Fig. 41. Renault Limousine.
Renault Frères Selling Branch, New York City.

It is apparent that these features of the torpedo style of body are especially convenient in taking long runs, and it therefore follows that this type of body may be considered a step forward in the evolution of the *touring* car.

The good features of the torpedo type of body, *i. e.*, the protection against wind and dust and the greater facility for keeping warm in cold weather, are shared by the high-power touring roadster

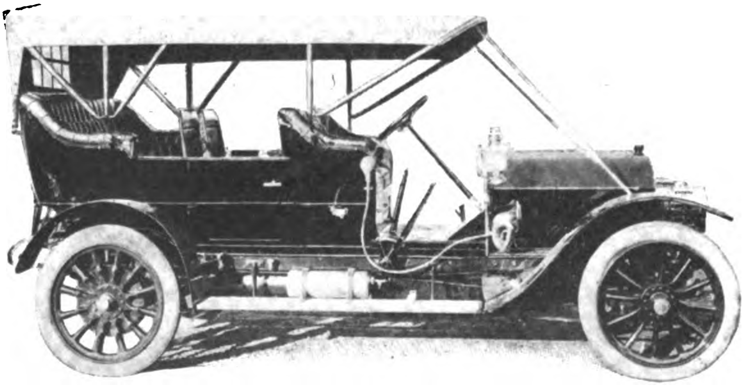


Fig. 42. Fiat Touring Car.
Fiat Automobile Co., New York City.

when the same lines of design are followed. This season several makers have offered special roadster bodies of the torpedo form, usually with the rear tool box or hamper tapered or rounded in order to give the wind an easy chance to close in. It may be expected because of the novelty of the style, as well as its inherent advantages on the road, that the popularity of this type of body will greatly increase.

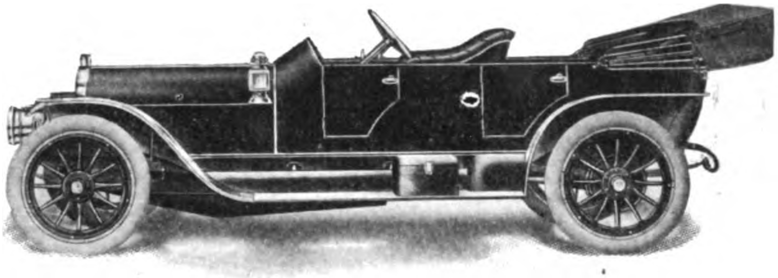


Fig. 43. Knox Gunboat.
Knox Automobile Company, Springfield, Mass.

A new feature which is on the increase is the use of large wheels for high-power touring cars and roadsters. Two makes of cars are now fitted with 40-inch or 42-inch wheels, and others will doubtless follow. Where such high wheels are used the most appropriate design is found in the underslung type of frame, which brings the center of gravity as low as it should be, despite the large wheel

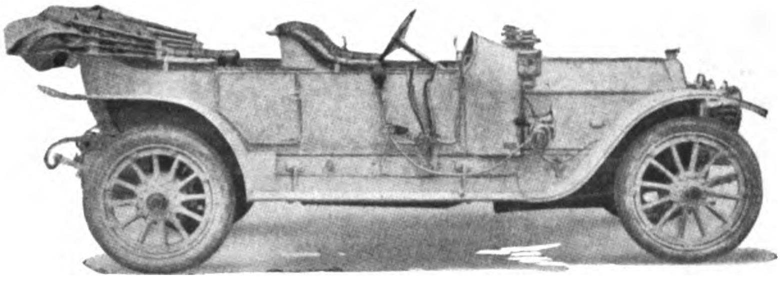


Fig. 44. Isotta Gunboat.
Isotta Import Co., New York City.

diameter. This type of frame is hung underneath the axles by means of long shackles connecting it to the springs.

TYPES OF TOWN CARS

Town cars form a class by themselves whose exact status has not been defined in either an engineering or utilitarian sense. The present practice is to use an engine of about 20 horse-power with three speeds, sometimes four, and very low gear to provide quick acceleration—an important feature in city driving. The driver's seat is in front of the closed portion of the body, which holds from two to five passengers.

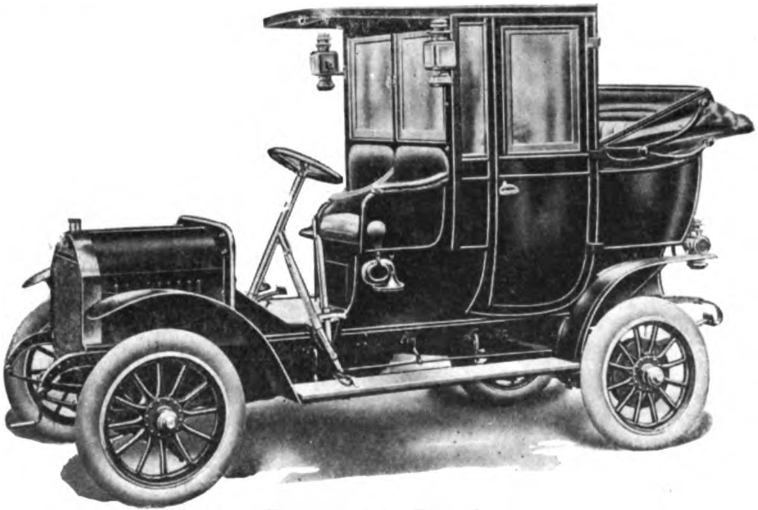


Fig. 45. Atlas Taxicab.
Atlas Motor Car Company, Springfield, Mass.

There is a decided tendency to use left-hand control in town cars, even when the touring models of the same makers have right-hand control. The reasons are that it is easy for the driver to get in and out when the car is driven up with its right side to the curb, and that in passing contrary-bound traffic the driver can see just how much room he has. The left-hand seat is also a convenience when one wishes to turn to the left of a cross street, as the driver can readily look back and see if another vehicle is about to overtake and pass him.

Aside from these small cars there are more or less numerous town cars of higher power, but at present most of these are specially con-

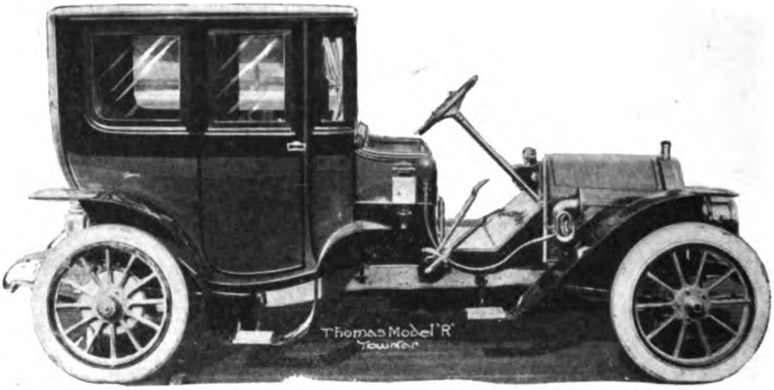


Fig. 46. Thomas Town Car.
E. R. Thomas Motor Co., Buffalo, N. Y.

structed as regards body to meet the views of their owners. Town cars, as a rule, have short wheel base and fairly large tire sizes.

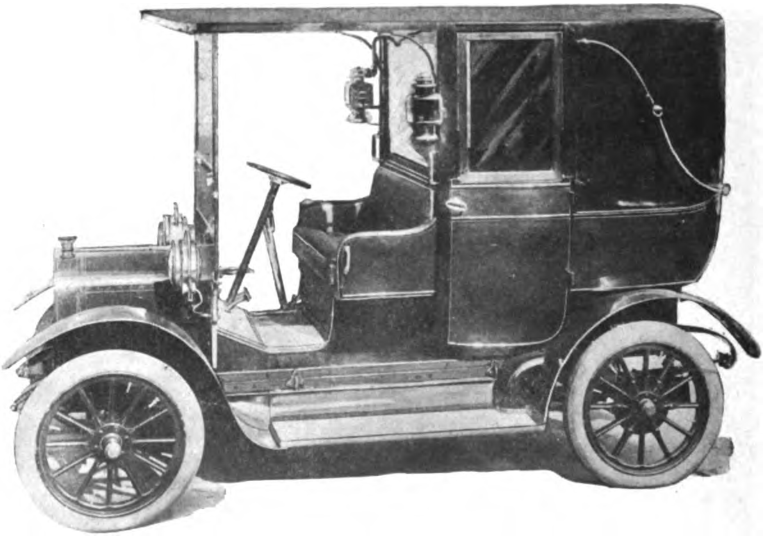


Fig. 47. Sultan Taxicab.
Sultan Motor Co., Springfield, Mass.

The different models of town cars which are given in Figs. 45 to 47 inclusive, represent as closely as possible the tendency of design in this type.

SPECIAL TYPES

Parallel with the typical cars above discussed there are two or three special types, mechanically speaking. Chief of these are the cars with air-cooled engines, and those with two-cycle engines. In body design, method of control, and intended service, these are not particularly different from the conventional cars with water-cooled, four-cycle engines. A third class of cars comprises a small number of makes with friction-disk transmission.

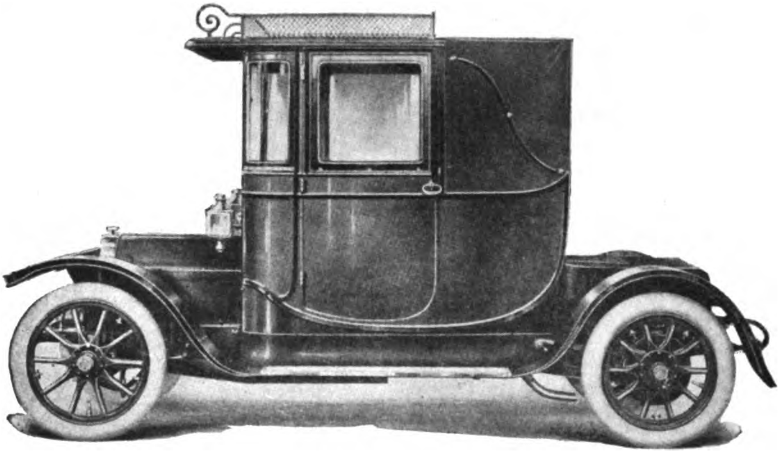


Fig. 48. Lancia Inside-Drive Coupé.
Hol-Tan Co., New York City.

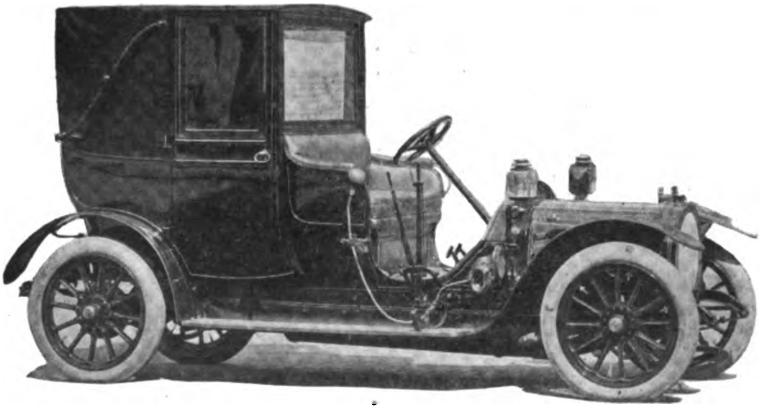


Fig. 49. De Launay Belleville Town Car.
Brewster & Co., New York City.

With the waning of the speed craze there has arisen in France a numerous class of small family cars which are practically miniatures of the large touring cars, but with engines of sometimes as little as 10 horse-power, Fig. 48, Fig. 49, and Fig. 50. These cars have three- or four-speed transmissions, roomy and comfortable bodies, and excellent mechanical construction throughout. The engine usually has four cylinders of small bore, but long stroke, so that it develops more power than its piston diameter would lead one to think. These small cars would be quite impracticable but for very reliable ignition and carburetion and excellent mechanical construction throughout, since it is evident that the slightest misfiring, leakage, or other loss of power in the engine would cripple the car.

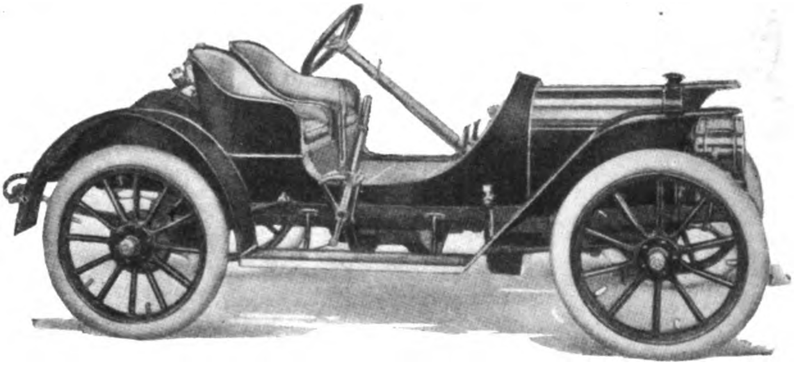


Fig. 50. Isotta Voiturette.
Isotta Import Co., New York City.

With the increasing cost of fuel and the growing tendency to regard the automobile as a utility vehicle it is probable that similar types of cars will become highly popular in this country.

SELECTING A CAR

The first step toward the selection of a car is the choice of motive power. If one wishes a car for less than $1,500, the choice must necessarily fall either on a gasoline car or on a steam car with fire-tube boiler, since the prices of electric vehicles and flash generator steam cars range above that figure. There are so many cars of different types at a price very close to this figure, however, that the matter of selection will be simplified if the question of price is eliminated till after the motive power has been considered.

CHOICE OF MOTIVE POWER

Electric. The advantages and limitations of electric vehicles, are well understood. Any woman, or even a child, can run them. They are not fast enough to be dangerous and they are very easy and simple to control. Their handicaps, other than of the price, are two, viz, the delicacy of the batteries which require an expert for their proper care, and the limited mileage possible on a single charge. The latter feature practically limits them to town use, and the former tends to lead the owner of an electric vehicle to keep it in a public garage where the business is sufficient to warrant the employment of a skilled attendant. The alternative is for the owner to become his own expert. If he has the time to devote to this, he will save considerable expense, as the rates for charging at garages are necessarily somewhat high because of the skilled character of the attendance required. In a word, the private owner of an electric vehicle, if he can store it on his own premises, need assume only the interest and depreciation on his private garage plus the cost of the charging outfit, plus the regular rates for current.

If the electric has been chosen, the task of selection need not detain us long. After the body style and carrying capacity have been settled, the chief remaining question is the battery. The choice here lies between the several standard makes of pasted plates and the Edison nickel-iron battery. The Edison battery will endure much rough usage, and on this account is preferred for certain classes of commercial work. Its efficiency, however, is very low; that is to say, for each unit of current spent in charging only half or a third of that unit of current is returned on discharge. Again, the efficiency is reported to vary considerably with temperature, being highest in summer and diminishing greatly in freezing weather. So far as pleasure vehicles are concerned, the preference thus far is for the standard types of lead cells.

As between one and another lead battery, the choice is mainly one of mechanical construction. A good vehicle battery must have its plates flexibly supported, with their bottom edges three-quarters of an inch above the bottom of the jar. This is to allow detached active material to fall clear of the plates instead of bridging between them and short-circuiting them. The cell must be properly ventilated yet sealed against slopping, and the terminals must be protected against corrosion so far as possible.

Steam. The place of the steam car is not quite so easily settled. With suitable replenishment of fuel and water its radius of action, like that of the gasoline car, is unlimited, and the choice between the two types is one rather of motive power than of simple adaptability to touring conditions.

To one who plays only the part of a passenger, and even to the novice receiving his first lessons in driving, the steam car is likely to seem far the more attractive of the two. It is quieter and smoother in action than any but the best six-cylinder gasoline car; its responsiveness to the throttle is superior to anything that even the best gasoline car can show; and the control members are fewer, and, for successful operation, require no such skill as is demanded in shifting the gears of a gasoline car. For these reasons the steam car has an especially large following among owners who employ chauffeurs, if not to drive, at least to keep their cars in working order. Many persons also, especially those unused to automobiles, object to the noise and vibration inseparable from most gasoline cars and prefer the steam cars for that reason. Still others, who wish the maximum in power, hill-climbing ability, and flexibility for the price, prefer steam cars for their superiority in these respects. Women frequently prefer steamers because of the absence of cranking and gear shifting.

Coming to the mechanical features, it is found that in steam cars, with the possible exception of the automatic devices regulating the fire and water, the cause of any trouble is not usually in doubt. This is because the steam power plant is purely a piece of mechanism, and when a piece of machinery goes wrong it is seldom difficult to detect the fact by sight or sound. The occasional exceptions to this rule furnished by the automatic devices are due to their comparative delicacy, their small size, and the fact that their working parts are concealed. The user in this situation must diagnose the trouble by induction and inference. For example, the weakest point of the old (not the present) White system was the thermostat, which occasionally would stick and become "burned out," owing to the fire not shutting off when it should. As the thermostat was located directly over the fire this resulted in its becoming crippled and failing thereafter to control the fire. The symptoms of this trouble, viz, excessive superheating of the steam—even to the steam pipe just outside the generator showing red hot—have proved very perplexing to users unable to trace the relation between cause and effect. Similar maladjustment of the fire-controlling needle valve of the flow motor in the present system would result in too much or too little superheat, but as the flow motor is not exposed to the fire it is not especially sensitive in that respect. On the other hand, such things as leaky slide valves, leaky water regulator valves, etc., are readily traced by their results.

Against these advantages must be set the important fact that as a mechanism the steam car requires more attention to keep in order than a well-built gasoline car. It depends on the use of water, steam, and fuel under pressure; and the numerous joints, packings, and valves of the water, steam and fuel systems must be kept tight. Since the steam pressure is two to four times that usually maintained in stationary and marine practice, this requires both excellent construction and more or less frequent inspection. The fuel is under less pressure, but the consequences of leakage are far more apt to be serious. Most of the fires that have occurred with steam cars have been due to the gasoline leaking and thus igniting from the burner. Of course, when the fuel is kerosene this danger is greatly reduced, since kerosene is not inflammable in the way that gasoline is, nor does it evaporate rapidly at ordinary temperatures.

The owner of a steamer must figure on five to ten minutes for firing up, and on shutting down the fire when the car is left standing. In severe winter weather it is hardly practicable to use a steam car at all, and, if used, it must be housed in a warm garage.

Gasoline. Turning now to gasoline vehicles, it is found that what appears on first sight to be a complicated array of mechanisms, reduces, on analysis, to considerable simplicity, and that this simplicity is combined with an inherent ruggedness hardly possible to attain with some elements of the steam car. The modern automobile motor is extremely durable, and there is nothing inherently delicate about the clutch, speed changing gears, or final drive. To operate the speed changing gears, when the latter are of the sliding type, certainly calls for skill, and this skill can only be obtained by practice. It is likewise true that a blundering or indifferent driver may never attain proficiency in this respect, although the gears will stand a great deal of abuse when carefully made of the right kinds of steel.

The weak points of the gasoline car are the carbureter and the ignition system; and these, like the automatic devices of the steam car, are more or less inherently delicate. It is impossible to make the carbureter rugged or massive in the same sense that the circulating pump may be rugged, and the same applies to the magneto or other ignition devices. The user must learn, first, to let these mechanisms alone till he understands their nature, and then to diagnose carbureter and ignition troubles from their symptoms. It has been said that when a steam car gets out of order it takes a minute to find the trouble and an hour to fix it, whereas when the gasoline car gets out of order it takes an hour to find the trouble and a minute to fix it. There is much truth in these remarks, since trouble with the steam car, if not due merely to leaky packing or sticking valves, is generally a matter of mechanical breakdown, which requires a new part or the aid of a shop to repair it. Trouble with the gasoline car, on the other hand, is most apt to be due to some slight loss of adjustment, sticking, or the like, in the carbureter or the ignition devices, and this, while frequently difficult to locate on account of its extremely inconspicuous character, is readily put right when found. Aside from this, the gasoline car is not simply a piece of mechanism. Its owner must know something of electricity, of chemistry (if he has a battery), and of the action of gases and vapors. Ten drops of oil or as many drops of water in the right place will cripple any magneto. A tiny particle of dirt in the spray orifice of the carbureter will bring the car to a standstill. There are scores or hundreds of possible troubles with ignition system and carbureter alone, any of which *may* happen some time, though few are *likely* to happen if a car is properly built. Most of them are trivial when recognized, but until the owner learns to trace them from their symptoms he is liable at any time to be stalled on the road by some mischance utterly insignificant in itself. Fortunately it is possible to say that skillful design and suitable protection have minimized these troubles.

CHOICE OF TYPE OF CAR

If the motive power chosen is either electricity or steam the restrictions as to type of car which this selection imposes, makes it unnecessary to discuss the subject further than has been done in the preceding sections. But this is not true of the gasoline car as the range of selection is so broad that the problem presents much greater difficulty. For many persons the purchase of an automobile is a serious step, a plunge into unknown financial waters, a gamble with themselves on the chance of developing the necessary mechanical aptitude for success. To the man with mechanical taste it may be said without hestitation that, by choosing the right car and caring properly for it, he can cover more miles in a year with less outlay of time and expense than he could with a horse. The same is usually true of men like physicians, who are accustomed to reasoning out their problems in an analytical manner. To the man without mechanical bent, however, or to the one whose occupation has given him no chance to learn how strong his tastes in that direction may be, the question is much less simple. Such a man has no business to begin his experience with anything but a high-grade car of comparatively small power. A low-grade car would give him too much tinkering to do, and a high-power car would be the worst kind of a "white elephant" on his untrained hands.

Owing to the diversity in the types and prices of automobiles today, there is little difficulty in selecting a car suitable for any sort of pleasure service, and for a fair range of business uses as well, at prices ranging from about $500 up.

If a car is to be bought solely for pleasure, or if it must make a good showing in economy, it is decidedly the best plan to begin one's motoring experience with a car of not over 4-inch bore (four-cylinder motors are here referred to). The moderate-power car is easier to drive; easier to learn; less expensive in tires, gasoline, and repairs; and if, as is quite possible, unskillful handling results in damage, the bills are far smaller than they would have been with a high-power car. The potentialities of trouble with the small car are also less, and its temptations to the owner, bitten with the speed craze, are less hard to resist.

Moreover, the novice can, if he is so minded, take care personally of a small car as regards the necessary daily oiling, adjusting, and occasional tinkering and minor repairs; whereas if he began his experience with a car of high power he would be compelled either to resort to the costly aid of a chauffeur, or to fall back simply on the maker's instructions to fill the tanks and radiator, and let the machinery alone. Such instructions suffice for the very best of cars, but the latter are a small class, and the novice who attempts to follow such advice runs the risk of neglecting incipient damage without realizing the fact, and presently being confronted with a costly repair bill.

Unless the first purchase is a small new car of high quality, it is a good plan to restrict the initial outlay to not more than $1,000 or $1,500. For this figure one may get either a new runabout, necessarily not of the highest grade, but still serviceable for a couple of seasons, or a high-grade car one or two years old. It is difficult to say which choice is preferable, as the personal equation is a large factor. If the first car purchased must last several years, it is better to get a high-grade car at second hand and bring it up to date, since such a car wears out less rapidly than the cheaper product. Purchasing in this way permits the selection of a car which will not be considered unserviceable when the educational first season is over. If, however, the owner can afford a taste for something up to date, it may be better to put the $1,000 into a small car for one year's use, sell it at the end of the first season for about $600 and purchase then a better car $2,000 or $2,500 to last several years.

In choosing a new car it is well for the inexperienced buyer to avoid makes which have not been on the market at least two seasons. Such cars may be good, but in the nature of things their past record is not sufficient to establish the fact. Occasional exceptions may be made in the case of cars by well-known designers. The general subject of second-hand cars will be taken up later. It is practically impossible for the beginner to judge a second-hand car with any degree of certainty, and he should either purchase from a conscientious friend or be guided by an unprejudiced expert.

Estimating the Cost. When expense is a consideration it is well, before choosing, to estimate the annual expense of ownership and use, as closely as possible. The first cost of a car is by no means always an index of the cost of running it. Some of the cheapest cars are among the most expensive to maintain. This principle applies especially when purchasing a second-hand car, as the first cost of such a car may be insignificant compared with the cost of keeping it in commission. If one cannot afford to purchase a 40-horse-power car new, it is not likely that he can afford to purchase it, or even accept it as a gift, when it is four or five years old. This does not mean that high-grade cars of that power are useless after four or five seasons; but their proper purchasers are men who can afford to run them and who care more for the saving in first price than for the up-to-date appearance of a new car. There is no reason why a first-class car should be considered worn out till it has run 100,000 miles, or three to four times the useful mileage of the $1,000 class of machines. As for the cheaper class of cars, they are seldom worth buying at any price when more than three years old.

The principal items in the cost of an automobile are as follows:

1. First cost of car and all extras
2. Interest on same
3. Depreciation in selling value
4. Repairs, annual and occasional
5. Tires, gasoline, oil, carbide, grease, etc.
6. Storage and washing charges
7. Chauffeur's hire, and incidentals
8. Clothing and personal expenses *en tour*

Of the above, some depend on the first cost of the car, some merely on the lapse of time, some on how much the car is used. Still others, notably the depreciation in selling value, depend both on the lapse of time and on the amount of use. Those which depend on use are to a large extent controllable by the owner himself. Repair and tire bills, particularly, may be four or five times as high for one man as for another with identical mileage, the only difference being in whether the tires receive proper care or abuse.

As so much depends on the price and quality of the car, the amount of use, and the driver, only very general statements can be made about the probable yearly cost. Some points which may be set down are as follows:

1. *First cost.* This is covered under "Types of Cars." For a runabout it will run from $600 to $1,000. For a 30-horse-power roadster or tonneau car it will run from $1,250 to $3,000.

2. *Interest.* If the car is stabled on the premises, interest should include not only the car, but the garage and the equipment. Something should also be charged off for depreciation on the latter.

3. *Depreciation in selling value.* This depends partly on how long a car is kept before being sold. A high-grade car may not lose more than fifteen per cent in selling value during the first year, *excluding tires.* If the supply is limited and new cars are selling at a premium, the drop in value at the end of the year may be very small. On the other hand, cars selling new at the lower end of the price scale are frequently half or a third worn out at the end of a season's

use, and bring correspondingly low prices. A car of a make which has made a bad showing for reliability, or whose builders are out of business may be almost unsalable after a few months' use.

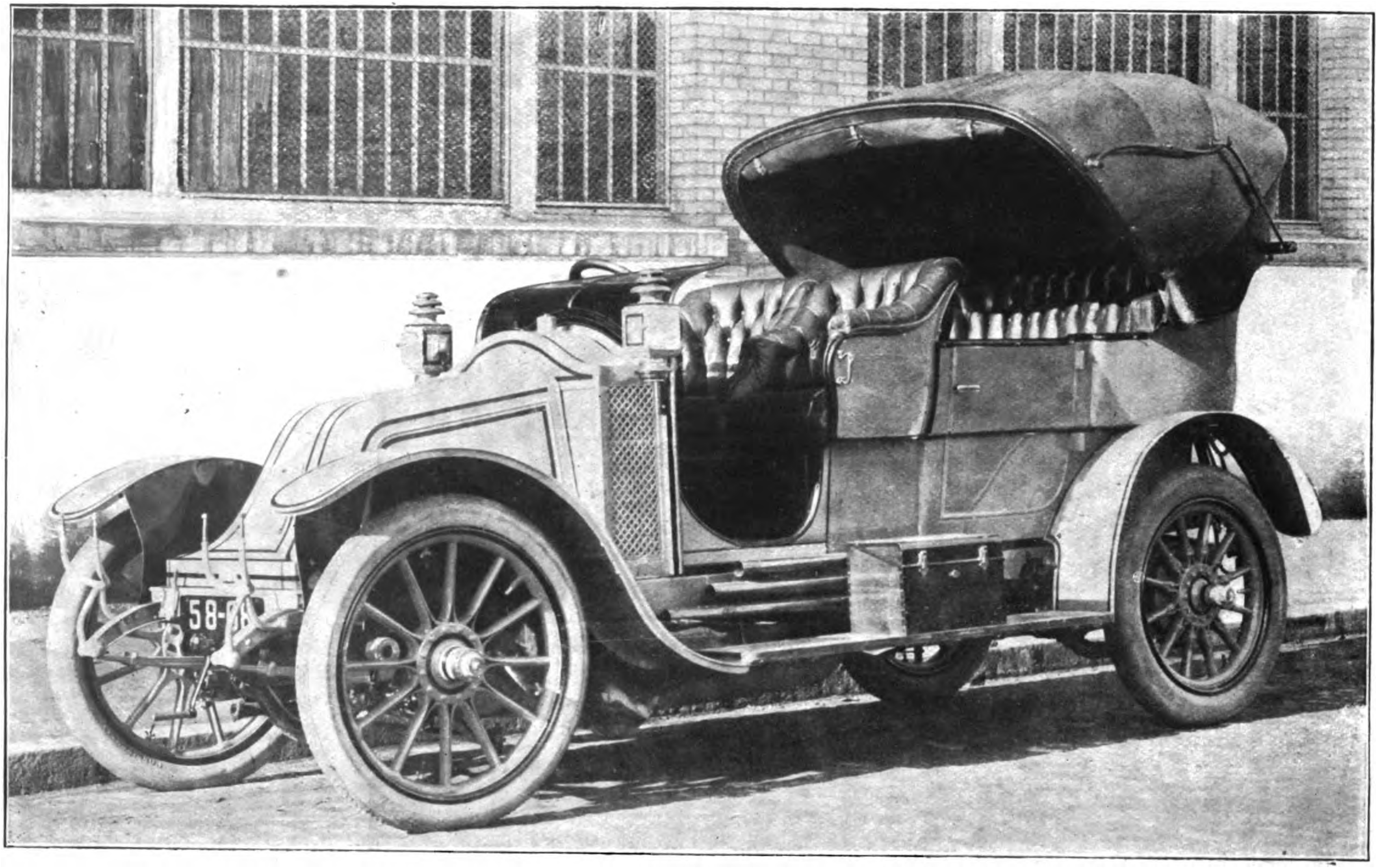
4. *Repairs.* The annual overhauling, which used to be a formidable item, is now greatly reduced through the use of anti-friction bearings, high-grade steels, and good design generally. It may run from $75 to $300, depending on the quality of the car and the use it has had. A high-grade car will need practically no shop work outside of the annual overhauling, but a cheap car is certain to need more or less tinkering to keep it in shape. As a general statement, a $1,500 car should not average over $150 for the annual overhaul, and a $3,000 car of the same power should keep within $100. The first year's work on each may cost considerably less. As they grow older the repair bills are increasingly higher, owing to certain parts wearing out in three or four years which needed no attention the first year.

5. *Tires and supplies.* Tire bills for the 30-horse-power car will run from 2½ cents to 4 cents per mile, depending on whether the tires are large enough for their work; whether they are kept properly inflated; whether cuts in the tread are vulcanized before damage results to the fabric; and whether or not the owner uses the clutch and brakes, and goes around corners in such a manner as to throw needless strains on the tires. Gasoline consumption will average about 15 miles per gallon, and oil 75 to 100 miles per quart, for the 30-horse-power car noted. It is safe to estimate the year's use on the basis of 5,000 miles' running.

6. *Storage and washing* in urban garages costs from $20 to $35 a month, sometimes more, according to the size of the car. If the car is stabled on the premises and cleaning is done by a handy man, a suitable pro rata of the latter's wages should be figured.

7. *Chauffeur's wages* run from $20 to $30 per week, according to place and conditions. If the chauffeur is dishonest and his employer is "easy," there are scores of ways in which the former can turn a profit, all of which in the end must come from the owner's pocket.

8. *Clothing* hardly comes in the scope of this book, but it is a more or less important item, and should be taken into account. Against the expenses of touring may frequently be credited the sum



RENAULT CABRIOLET, A TYPICAL FRENCH MAKE
Renault Frères, Billancourt, France.

which would otherwise be spent for vacation at the shore or in the mountains.

The expenses above indicated apply to medium-priced cars except where otherwise stated. A light runabout will cost considerably less in almost all particulars. For example, the tire bills may not be over half those of the 30-horse-power touring car; the gasoline consumption will be correspondingly less; and the depreciation and repairs will be about in proportion to first cost, provided the mechanical quality of the car is equally good. If, however, the small car is flimsily built it will wear out in two or three seasons, and the depreciation and repair bills will be correspondingly high.

To go to the other end of the scale, the expense account of a high-powered car is found to be fully in proportion to its horse-power and price. The gasoline and tire bills will bear a rough relation to the weight and power of the car, whether it be mechanically of high or low grade. The high-grade car, however, will be far more economical in repairs, and, in fact, may cost no more in this respect than the average cars of medium power dealt with above. A cheap high-power car, on the contrary, is a money eater.

The largest item of expense of any car whose speed average on the road is 25 miles an hour or over is the tires. At high speeds the tread of the tire is cut by sharp stones, etc., which could not injure it at lower speeds. At high speeds also one is apt to skid on turns, and to set the brakes harshly, both of which things are destructive to the tires.

Selecting for Specific Purposes. The precise purpose for which the car is intended will often modify the choice in some important details. For example, if the car is to be driven by a lady it is better to have a planetary gearing, at least until she has thoroughly mastered that type of car. A battery system for starting is also essential for a woman driver, so as to avoid the necessity for "spinning" the crank to get a spark from the magneto. If the car is to have sliding gears, the number of speeds—two, three, or four—will depend on the power of the car and the character of the country in which it is to be used. As has already been stated, the two-speed sliding-gear transmission is desirable only as an alternative to none at all. If the power be small, three speeds will be sufficient, but any car of 40 horse-power or more should have four speeds to be thoroughly satisfactory, and many drivers prefer four speeds whether the power be high or low. A four-speed transmission is especially useful in hilly districts. If the roads are level and smooth, so that one can stay in high gear practically all the time, the fact that one has but one instead of two intermediate speeds it not often noticed.

As regards ignition, it is well to remember that, though a high-grade magneto is the first choice, a cheap magneto is not as satisfactory as a good battery system. The weak point of the battery system is the vibrator coil; there are one or two systems which eliminate the vibrator and are exceedingly reliable, though requiring adjustment a little more frequently than magnetos.

Between air-cooled and water-cooled engines, the most important determining factor is the temperature in which the car is to be used. In summer weather water cooling has a certain advantage over air cooling; but no one likes to be bothered with non-freezing mixtures, and if the car is to be used regularly in severe winter weather it is much simpler to sidestep the freezing question by having a good air-cooled car.

Runabouts for Business Purposes. It is easier to select a car purely for pleasure use than for some special business requirement. It may, in fact, be said that the automobile for the business and professional man has not yet been produced. Physicians whose work takes them into the country have to purchase pleasure runabouts and adapt them to their purpose, and the same is more or less true of real estate agents, contractors, and salesmen, who can cover a certain limited territory better by automobile than by other means of travel. Since the business automobile, unlike the pleasure vehicle, must be used in all weathers, and since a breakdown is practically inadmissible, it cannot be too reliable or too automatic in all matters pertaining to lubrication, ignition, and carburetion.

The intending purchaser of a business runabout will do well to hold the following specifications in mind as closely as possible: *Body*, runabout or roadster type, with folding top, hooded dash, storm curtains, and side panels between dash and seat to exclude wind; *motor*, 4 cylinders, 3¾-inch to 4-inch bore, 4¼-inch stroke; *ignition*, high-tension magneto with battery reserve; *carbureter*, hot-water jacketed and fully protected against mud; *cooling*, by water south of the latitude of Philadelphia and Indianapolis, by air in the northern States if car is to be used all winter; *clutch,* leather-faced cone or multiple disk; *transmission,* three or four speeds and reverse, direct drive preferably in third speed; *wheel base,* 100 to 110 inches; *wheels,* 36 inches diameter with 3½-inch or 4-inch quick detachable tires or demountable rims; *final drive,* by propeller shaft with two universal joints; *rear axle* construction to include torsion frame separate from propeller shaft, and also radius rods; *brakes,* two sets, foot brake on gear shaft or rear wheels, emergency brakes on rear wheels, both sets to be readily adjustable without tools.

The equipment should include wind shield, large headlights, also swivel searchlight if much night work is to be done, gas tank or automatic generator, and tools for making quick tire changes on the road, in case those of the pneumatic type are used. There are certain cushion tires which offer nearly the equivalent of the pneumatic in easy riding and road resistance, and which are not subject to puncture or blowouts. For doctors, and also for women drivers, these tires appear to have a special usefulness.

SECOND-HAND CAR

Gasoline. As regards horse-power and body style the same principles apply in selecting a second-hand car as a new one. One must, however, guard against the temptation to purchase a car of higher power than one can afford, simply because the purchase price is small. The repair and maintenance charges of any second-hand car will be higher than those of a new car, and one must figure liberally in this regard to avoid disappointment.

In choosing a second-hand car it is well to check the owner's or dealer's statement of its age by noting the serial number of the car and inquiring of the makers or agent to what year it belongs. Most cars have also certain distinctive marks, such as the shape of the bonnet, the shape of the hub caps, the details of the ignition system, etc., which distinguish them from otherwise similar cars built earlier or later. These afford another check on the age of the car.

A car two years old may have been run 5,000 miles or 20,000 miles, and much depends on this point. The condition of the paint will often tell how much usage the car has had. Another criterion is the condition of the steering gear, since wear is usually most rapid at this point. Grasp one of the front wheels by the spokes and work it to right and left, noting how much it deflects before the steering wheel turns. Push sideways against the top of the wheel, and note how much wear the steering knuckle pivot shows. Note whether the steering column oscillates when the steering wheel is turned to right or left: if it does, the bolts holding the base of the steering column may be loose. Jack up each wheel in turn, and by shaking it note whether the bearings are loose. Loose ball bearings will have to be replaced. Jack up one of the rear wheels, engage any one of the gears and rock the wheel back and forth to show how much looseness there is in the transmission line. This looseness will be distributed between the differential gears, the bevel driving gears, the cardan joints of the propeller shaft, and the speed-changing gears themselves. Most of it is likely to be in the differential gears, which are hard to examine directly. It is usually safe to assume that these will need replacements anyway. If the cardan joints are loose, they should also be replaced or rebushed.

Take off the gear case cover and examine the gears with the aid of an electric light, feeling of the teeth if necessary. Certain gears are likely to be much more worn than others, and if the teeth have lost their rounded profile, or if their sides have been worn away where they strike each other on shifting, new gears should be supplied.

Run the engine and note its sound. It should be reasonably quiet when running idle on low throttle, and should not be excessively noisy when accelerated. It should be free from periodic knocks, one per revolution or one every other revolution. If a knock is heard, endeavor to trace it by pressing one end of a stick against the casing near the suspected part, the other end being held against the chin. Stopping the engine, shake the valve stems and valve lifters between thumb and finger to test their looseness. The valve stems will bear some shaking, but if the valve lifters are loose they will be noisy.

When the car is run for demonstration, listen for nosies, as these are the truest index to its condition. If the engine knocks when pulling up hill, either the bearings are loose or there are carbon deposits on the piston heads. If the engine runs hot on hills, the radiator or piping may be clogged or the ignition may be irregular. Note whether the transmission gears are noisy when transmitting power, also note whether gear shifts are made easily and quietly.

If high gear engages noisily or with difficulty, it is probably due to the teeth of the jaw clutch being worn rounded.

Take advantage of the demonstration run to test the engine power on hills, the flexibility of the engine—*i. e.*, its ability to slow down in high gear without stopping and pick up again when the throttle is open—also the holding power of the clutch and brakes. Remember, however, that the engine power is largely a question of carbureter and ignition, and if either of these are faulty the engine will not show its real capabilities. Remember also that worn brakes may be replaced, but that, if lack of holding power in the brakes is due to small size, it cannot be materially improved.

Much depends on whether the car is offered as being in first-class condition and ready to run, or whether the purchaser expects to overhaul it at his own expense. In the former case the car may properly be debited for any weakness in performance, while in the latter case the purchaser must be a good judge of cars to note how far the seeming defect may be overcome. Many an engine has been rejuvenated simply by putting on an up-to-date carbureter and ignition system, or merely by correcting the valve timing.

If the car is supposed to be perfect as it stands, the demonstration run should not be too short—a twenty to fifty mile run should in most cases be insisted on. At the end of the run, test the compression by turning the crank slowly with the spark cut off. If the cylinders do not hold compression well, new piston rings are likely to be necessary, since it may be assumed that the valves are in good shape.

In appraising the value of a second-hand car, do not lay too much stress on what the car was worth when it was new. If it is several years old, equally good cars are to be had today for half or two-thirds as much money. Assume, therefore, that the car under consideration was worth when new as much as similar cars today, and then scale its price down, according to the wear it has received and the probable cost of putting it in good condition. Remember that, even when the engine, transmission, and steering gear have been thoroughly overhauled, there will be numerous minor bearings all over the car which in the nature of the case can hardly be replaced save at prohibitive cost. Such are the joints of the steering mechanism the gear-shifting mechanism, the brakes, the radius rods, etc. All of these, gradually wearing loose, will in time make the car noisy, even when the power plant is in excellent condition.

When the condition of the car has been ascertained, estimate as nearly as possible what it will cost to overhaul it. Add the cost of new tires where needed, and credit the car with the value of extra equipment, if any. Then compare the total prospective cost of the car with the total cost of a similar new car fully equipped, and make suitable allowance for the wear and tear the car has already had. In this way a fair appraisal of the car's value may be obtained.

Steam. In selecting a second-hand steam car, the first thing to remember is that, from the nature of their mechanism, steam cars do not usually last as long as gasoline cars of equal mechanical quality. A high-grade steam car, for example, will be worn out in three or four years, whereas an equally good gasoline car would last twice as long. The reason for this is partly that the boiler or generator and the various auxiliaries, automatics, and fittings under pressure wear out somewhat rapidly, and partly that the engine, since it develops more power in smaller compass, necessarily tends to wear itself out more rapidly.

A steam car requires the same examination of the mechanical parts for wear that the gasoline car does. For example, the steering gear, the propeller shaft, or sprockets and sprocket chains, the bearings in the front and rear wheels, the rear axle and the brakes, should all come in for examination. The propeller-shaft-cardan joints of a steam car wear out much more rapidly than those of a gasoline car, due, probably, to the fact that the steamer cannot, like the gasoline car, be unclutched momentarily when going over rough spots. Every road jolt involves a more or less abrupt, momentary change in the angular velocity of the wheels and transmission shafts. If the wheels are disconnected from the engine there is only the inertia of the clutch to be overcome, but with the two rigidly connected the transmission members must stand the whole jerk, transmitted from the wheels to the engine.

Have the car fired up in your presence, noting the procedure and how long it takes. Notice if the burner and pilot flames are hot and clear blue in color. After the water is worked out of the engine run the car with the front wheels against a wall, and open the throttle. If steam escapes from the exhaust it shows that the slide valves or piston rings leak. Notice how long it takes the power air pump to raise pressure. If the tank is full it should take but a few moments; if the pressure comes up noticeably slowly, the air check valves probably leak.

If the country is hilly, test the steaming power on the hills. Notice whether the fire comes on and off cleanly in response to the automatic control. If the burner lights back, insist on having the trouble corrected before you accept the car. A White steamer with flow motor should require very little running to enable it to take a hill. Other types of steam cars must have the throttle opened long enough before striking the hill to insure the fire being on when the foot of the hill is reached.

Note how far the engine can be hooked up when running fast. If the engine pounds with late cut-off on low throttle the bearings are loose, or the valves are improperly adjusted. Loose cardan joints in the propeller shaft will rattle under the same condition, especially just when the throttle is opened.

Electric. When selecting an electric vehicle, first investigate the condition of the mechanical elements, *i. e.*, gears, bearings in wheels and transmission, steering gear, commutator and brushes. Examine also the controller to see how far the contact segments are burned away.

Aside from the above, the main question is the condition of the battery, and this can only be fully settled by an expert. The user, however, can satisfy himself fairly well by having the battery fully charged, and then making a test run of the machine, say at twelve miles speed, over smooth level roads till the charge is exhausted. The ideal test will be to run the car over average roads such as will be met in service, but this might involve a troublesome tow at the end of the test. The alternative is to run it around the block. When the voltmeter shows that the battery is discharged to 1.8 volts per cell, the mileage should be noted. Before and after the run the voltage of the individual cells should be tested. If any cells are found defective it is best to allow for the cost of new cells.

It will be good policy to remember that any lead storage battery is only good for a limited number of charges (usually 40 to 50 complete charges and discharges). Furthermore, although the efficiency when new is nearly 80 per cent and holds up well for the first dozen or twenty charges, its capacity thereafter diminishes almost in proportion to the number of discharges.

KNOW THY MACHINE

New Car. The beginner with a new car is strongly tempted to plunge at once into hundred-mile rides and week-long tours. This is a mistake in several ways, chief of which is that it is a strong invitation for trouble in case something goes wrong with the car. Until one understands every detail of the machine, and particularly the details of ignition and carburetion, a very trivial mishap may present formidable perplexities.

The subject of learning to drive is dealt with in another part of this course, but even the owner who already knows how to drive has something to learn about the pecularities of any new car that comes into his hands. Before attempting to drive, one should learn everything possible about the four cardinal points, *ignition, carburetion,* *lubrication,* and the *gasoline tank, pipe and shut-off valve.*

Learn whether ignition is by magneto or by battery, and if the former, whether the magneto is of the true high tension type or a low tension magneto with step-up coil and distributor. A few cars have make-and-break igniters with low tension magnetos. The action of these igniters should be thoroughly studied, and one should know how to remove the igniter plates to clean soot from the inner insulation, and also how to adjust the timing, so that all will fire at the same crank angle. Learn if there is a battery for starting purposes, and what is the retarded position of the spark lever. If batteries are used, test them to see that they are not exhausted when you get the car.

Examine the carbureter to see how it is primed for starting. Some carbureters are primed by depressing the float, others by closing a choke valve at the carbureter intake. If the careburter has a hot-water jacket, look for the valve which controls the water circulation through it. If there are adjustable hot- and cold-air intakes, see that they are adjusted according to the season.

Familiarize yourself thoroughly with the lubrication system of the engine. If oil is fed by a mechanical oiler through individual pipes to the bearings or crank case, see that all the pumps of the mechanical oiler are working, and that none of the oil pipes leak at their joints and unions. If oil is circulated from the crank case to the bearings and back again by a pump located at the base of the crank case, take out the screen through which the pump draws oil and see that it is clean. Probably the crank case or oil reservoir has a test cock at the proper oil level; see that oil of the proper grade is poured in until it comes out of this cock when the latter is opened. Some large cars have the main oil tank located back of the engine under the footboard, and oil is pumped from this to an auxiliary tank, or to the mechanical oiler. If there is such a tank, locate it and see that it is filled.

If the clutch runs in oil, learn from the makers what grade of oil is used—it may not be the same in summer and winter—and see that the proper quantity is supplied.

Ascertain what lubricant is proper for the transmission gears. If the gear shafts run in ball or roller bearings throughout, thin mineral grease is dangerous for the reason that it cannot be trusted to work its way through small oil holes. Many gear cases have anti-friction bearings throughout with the exception of the "pilot" bearing inside the main driving pinion. In this bearing runs the front end of the squared or feathered shaft, carrying the sliding gears, and for lack of room it is often plain bushed. With grease lubrication, such a bearing is liable to cut; heavy "gear case" oil must therefore be used.

Usually the cardan joints of the propeller shaft are encased and filled with thin grease, and sometimes they have individual grease cups. Looseness in the cardan joints is at least annoying, and due attention should be paid to their preservation from wear.

The rear axle casing is usually filled one-third full with gear case oil, to which in summer a little grease may be added. Thick grease is undesirable, as it sometimes fails to work into the bearings of the differential pinions, and these, therefore, get dry and cut. If too much oil is put into the axle casing, it will work out to the wheels and get on the brake drums.

The numerous grease cups and oil holes scattered about the car are quite as important as the major lubricating systems. A car whose engine or transmission is worn out may be overhauled at moderate cost by putting in new bushings and gears, but when worn out in respect to the minor bearings it is nearly hopeless; for, except in the highest-priced cars, these are seldom bushed or otherwise fitted to take up wear. Therefore the grease cups should be given a turn each day when starting out, and refilled when necessary, and the oil-can should be used as indicated.

Ascertain the location and capacity of the gasoline tank, and note whether the carbuteter is fed by gravity or by air or exhaust pressure. Learn where the shut-off valve is, between the tank and the carbureter, and make a practice of closing it after every run. Few carbureter float-valves are so tight that they permit no leakage whatever, and the fact that the carbureter does not leak today is no guarantee that it will not leak tomorrow. If pressure feed is used, familiarize yourself with the pressure relief valves between the exhaust manifold and the tank, and the pressure gauge on the dashboard. The strainer or separator, which prevents water condensed from the exhaust gases from getting into the gasoline tank, should also be noted, and the method of cleaning it understood.

One is under no obligation to assume that a new car fresh from the factory is likely to go wrong in the first hundred miles. Nevertheless, it frequently happens, especially with the cheaper classes of cars, that one or another minor detail may not be up to the standard of the car as a whole. For example, the battery box, if of wood, may be strong enough to hold dry cells, but too flimsy to hold a heavy storage battery. The ignition may be hastily installed, the spark and throttle connections may be a trifle too long or too short to give the full range of control, and there are numerous other possibilities of minor trouble which the user may need to find out and correct before he gets the best service from his car. It is always best for the first few weeks to keep fairly close to home and help, till one is satisfied that these possiblities have been eliminated, and the car as a whole is fully "tuned up" to its work.

Second-Hand Car. The remarks of the preceding chapter on getting acquainted with a new car apply with three-fold force to the used car whose exact condition is not fully known, and which is probably not accompanied by the maker's book of instructions. In addition to all the precautions enumerated above, one must be on the alert for signs of possible defects. Unusual sounds in the engine should be investigated. They may be due to irregular firing, to looseness of some bearing, to heating up, or to other causes. The remedy is not usually difficult to prescribe when the cause is known. The radiator should be watched for leaks and felt by hand to determine whether the water is circulating properly. The gasoline pipe and carbureter should be watched to see that there is no leakage. Occasionally a pipe union or the carbureter itself may leak, but not enough to cause noticeable dripping. Touching the fingers underneath, however, will tell the story.

Be sure that the engine gets enough oil. Until you know positively that the oiling system is working properly, it is better to feed the engine too much than too little. If a mechanical oiler with individual feeds is used, it is a safe plan to disconnect one oil pipe at a time, where it goes into the engine, and note by running the engine whether oil comes through it or not. If the engine smokes, it is a good sign that it is getting enough oil. Sometimes, however, the oil feed may be such that one or two cylinders may be starved of oil while the others get enough or too much. This will usually be shown by the smoke puffs of the exhaust being intermittent instead of smoothly continuous. If the cylinders are separately oiled, the deficient one may be traced by disconnecting the oil pipes at their ends. If they are oiled by splash the forward or rear part may not get its share, owing to the oil being low in the forward or rear oil pan. Some engines have individual pans or troughs, one under each cylinder. These should be arranged so that oil entering one will distribute itself to the others as soon as the proper level is reached. If, however, there is not enough for all, one or two may be starved. If the oil is circulated by pump from an underneath reservoir, there is not much danger of any of the cylinders being starved, as the pump throws many times the permissible minimum supply. When one is satisfied that no part of the engine is being deprived of oil, the feed may be reduced gradually until there is only a slight show of smoke in the exhaust.

As one does not usually know when buying a second-hand car what is the state of the oil in the transmission and rear axle, it is best to clean it out altogether and supply fresh oil. One should by no means use the car to any extent till satisfied that all the gears are properly lubricated.

The brakes should be examined for wear, and if taken up nearly to the limits of their adjustment they thould be relined.

Aside from the foregoing specific points, watch should be kept all over the car for things working loose—for example, the various joints, etc., of the steering gear, the bolts holding the base of the steering column to the frame, the spring clip bolts, the holding-down bolts of the engine, and the various parts of the propeller shaft, cardan joints, etc. If cotter pins are missing they should be supplied at once. If any particular nut or bolt betrays a chronic tendency to loosen, special means must be found to lock it. It will usually be found that the trouble lies in the bolt being too small to fill its hole, or in not being prevented from turning.

REVIEW QUESTIONS

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are samples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AUTOMOBILES

PART I

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1. Name the principal working parts of a simple double-acting steam engine.

2. Define *radiation, absorption, conduction,* and *convection.*

3. State Boyle's Law.

4. What is absolute zero? What molecular state does it theoretically represent?

5. Define *force, work,* and *power.* What is a *horse-power?*

6. Define *British thermal unit.*

7. Define *latent heat.* How many British thermal units are absorbed in boiling away a pound of water at atmospheric pressure?

8. Why is the explosion of a stationary boiler so destructive?

9. Define *superheat.* What is its object?

10. Sketch roughly a D slide valve.

11. Define *lap* and *lead.* What is the *angle of advance?*

12. Describe the *Stephenson link motion,* and give a rough sketch of the same.

13. Under what circumstances is gasoline vapor explosive? How may it be ignited?

14. Describe the construction of the Stanley boiler.

15. What is a *fusible plug,* and what is its purpose?

16. How is the fire regulated in the Stanley and Lane cars?

17. Explain the principle of the thermostatic water-level indicator.

18. How should the throttle of a car with fire-tube boiler be managed on approaching an up-grade? A down-grade?

19. Describe the general process of firing up a car with fire-tube boiler and getting ready to run. In what particulars is caution especially necessary?

20. What is the object of blowing down the boiler, and when should it be done?

21. How is the boiler most easily filled with water for the next firing up?

22. What is the most frequent cause of low pressure and its remedy?

23. Describe the arrangement of gasoline pressure tanks in the Stanley car. How does the driver know when additional air is required in them?

24. Describe the use of the blow-off valve in firing up the Stanley car.

25. State two possible causes of the Stanley water pump failing to work.

26. State two possible causes of poor fire in the Stanley car.

27. When starting from rest, in a car having a compound engine, what else must the driver do besides opening the throttle?

28. Name the principal packings which need adjustment, and state which should be packed tight and which may be slightly loose.

29. Besides the hand by-pass valve, what other device has the Lane car for controlling the water feed?

30. What must be done to *lay up* the Lane or Stanley cars in freezing weather?

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AUTOMOBILES

PART II

1. Describe briefly the *flash steam generator.* State fully the particulars wherein its action differs from that of the fire-tube boiler.

2. In the theoretical (extreme) case what is the reserve capacity of the flash steam generator?

3. Referring to the White system of 1904 to 1905, state (*a*) how the water supply was regulated; (*b*) how the burner was regulated.

4. State the two chief drawbacks of the White system of that date.

5. Draw a rough sketch of the *flow motor* and name the principal parts.

6. Where is the *thermostat* located, and what is its action?

7. Describe clearly the action of the flow motor and thermostat (*a*) when the pumps are running fast enough to force the flow motor piston to the end of its travel; (*b*) when the pumps (and therefore the car) are running slowly.

8. What is the emergency gear, and how is it operated?

9. In what respects do the fuel arrangements of the 1909 and 1910 White cars differ?

10. What is the *warming-up valve,* and what is the course taken by the fuel after passing through it? Does the warming-up valve of the 1910 car take gasoline or kerosene? How long should the warming-up valve be kept open?

11. When empty how is the generator filled with water? How may it easily be filled on finishing a run?

12. Describe how to light the pilot light.

13. State the several steps necessary to start the car from cold, raise air pressure, and warm up the engine.

14. Should the burner valve be left open or shut, when the car stands idle, and why?

15. What determines the shortest practicable cut-off when running?

16. What parts in the water system require occasional cleaning?

17. Why and how are the pilot light and vaporizer cleaned?

18. When is the fuel valve of the flow motor correctly adjusted?

19. What precautions are necessary in dismounting and reassembling the water regulator?

20. What points in the engine lubrication (other than refilling the oil tank) require occasional attention?

REVIEW QUESTIONS

ON THE SUBJECT OF

COMMERCIAL VEHICLES

PART I

1. Give the general specifications of two makes of electric delivery vehicles.

2. Show in what fields the electric vehicle excels and why.

3. What particular advantage has the planetary transmission over the selective type on the commercial car?

4. Are there any marked changes in the specifications in passing from electric delivery wagons to trucks?

5. What are the standard requirements of taxicab service? Give a brief description of one type.

6. What limitations are placed on the load capacity of the gasoline truck? State why such limitations exist.

7. What limits the range of usefulness of the electric delivery wagon?

8. What is meant by *load efficiency?* How does this vary with the size of the vehicle and why?

9. Why did not the ordinary pleasure car adequately fill the needs of the taxicab?

10. Give general requirements for a commercial car and show in what particulars the pleasure car falls short.

11. Describe the *couple-gear* truck and show its advantages.

12. What is the friction drive and what are its advantages? Can this form be used on very large delivery wagons?

13. What limits, if any, are placed on the size of an electric truck?

14. Name the advantages and disadvantages in the use of Edison storage batteries in comparison with the regulation lead battery.

15. Show how the tire question is handled in the taxicab service.

16. Give advantages and disadvantages of the 2-cycle motor.

17. How can an internal combustion motor be made to give comparatively high efficiency on low speed?

18. Give the general specifications for a gasoline truck.

19. Give the general scheme of hydraulic transmission.

20. Give the usual form of springs on the gasoline delivery wagons and trucks.

REVIEW QUESTIONS

ON THE SUBJECT OF

COMMERCIAL VEHICLES

PART II

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1. What form did the early tractors take?

2. Give some of the methods by which the different manufacturers produce the amount of traction required to run a gang plow, for example.

3. What fuel is most common among tractors and why used?

4. Describe in detail the Sampson road train giving particular attention to the control mechanism.

5. What points are in favor of a road train in the transportation of a large amount of materials as compared with the individual trucks?

6. To what extent has the gasoline vehicle been applied to municipal fire service? Give some examples and show how this equipment has been developed.

7. What particular phases of the heavy vehicle problem are admirably solved by the gasoline-electric type?

8. Give mileage per gallon of fuel for a few of the important types of commercial vehicles.

9. Give figures to show the total cost per mile of a 5-ton and a 10-ton truck.

10. Can either gasoline or kerosene be economically used in an engine without change of the accessories? If not, why not?

11. Discuss the merits of alcohol as a fuel.

12. Give the general details of a producer-gas outfit for an automobile. What are its advantages? Disadvantages?

13. Compare the merits of rubber, steel, and wood as material for commercial tires.

14. Describe some of the methods of obtaining sufficient traction and rigidity with rubber tires on large trucks.

15. As an expert in commercial vehicle usage, you are requested to specify motor equipment to take the place of 100 one-horse delivery wagons, and five two-horse trucks. Fifty of these small delivery wagons receive their supply of packages direct from headquarters and cover routes averaging 26 miles daily travel. The five two-horse trucks are employed for transporting full loads to outlying distributing stations, the most distant of which is 18 miles from the store. The remaining fifty delivery wagons are attached to these outlying stations and serve routes averaging 32 miles daily travel. How many and what type of vehicles would you specify to displace the horse-drawn equipment?

16. You are called in an advisory capacity to discuss the question of motor equipment by a large wholesale house. The service required is of two distinct classes. First, loads averaging from two to four tons must be transported from the warehouse to steamship piers and railway depots—average distance 2½ to 3 miles. Second, loads of four to five tons must be transported from the factory, eight miles distant, to the warehouse, and loads averaging three tons must be carried from the warehouse to jobbing customers situated at distances of from four to ten miles. State the nature of the equipment you would specify as the best adapted to meet every one of these conditions.

REVIEW QUESTIONS

ON THE SUBJECT OF

TYPES OF AUTOMOBILES

1. Discuss briefly the steps in the development of the present type of pleasure automobile.
2. Contrast the steamer and gasoline car of the same price and power and show the superior points of each.
3. What are the characteristics of a high-priced touring car? In what particular is the extra price justified?
4. Is it wiser to buy a second-hand, high-power car or a new medium-priced car? Justify your answer.
5. What sort of specifications can one expect for $1,500 in a roadster type?
6. Mention the points to be considered in buying a second-hand gasoline car.
7. Give the advantages of six cylinders over four.
8. Give the characteristics of the following types: runabout, roadster, touring car, limousine, landaulet.
9. How do you test the batteries in buying a second-hand electric?
10. Under what conditions should an electric vehicle be considered for purchase? Why?
11. Give some of the factors to be considered in estimating the total cost of an automobile.
12. What changes will be noticed in a roadster for $1,000 as compared with one for $1,500 to $2,000?

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